



INTRODUCTION MODULE

Introduction to National Green Infrastructure Certification Program and Stormwater Basics



NGICP TRAINING COURSE LEARNING OBJECTIVES



- ▶ Share information on technical and programmatic aspects of green infrastructure as it relates to construction, inspection and maintenance.
- ▶ Provide a vehicle for qualified trainers to share in-class and in-field to relay knowledge that is tied to the NGICP Body of Knowledge.
- ▶ Prepare participants to take the qualifying test associated with the NGICP in hopes that participants become Certified Green Infrastructure Constructors, Inspectors and Maintainers.

LEARNING OBJECTIVES

Provide basic information on the stormwater sector and to understand the context of the NGICP, including:

- ▶ What is the National Green Infrastructure Program?
- ▶ How is the NGICP structured?
- ▶ What information is covered in the course and how is testing tied to this information?
- ▶ What is “stormwater”?
- ▶ Why does it matter?
- ▶ What are common terms used in the stormwater field?
- ▶ What are types of jobs associated with the stormwater field and how does the NGICP help you prepare for these jobs?



National Green Infrastructure Certification Program (NGICP)



Information Covered:

- ▶ Background Information
 - ▶ Introduction to stormwater management and green infrastructure
 - ▶ Materials and vegetation used in GI practices and systems
 - ▶ Safety, site management, and managing for long-term performance
- ▶ Green Infrastructure Practices
 - ▶ Bioretention
 - ▶ Permeable/porous pavement
 - ▶ Rainwater harvesting
 - ▶ Green/blue roofs
 - ▶ Dry wells
 - ▶ Constructed stormwater wetlands

National Green Infrastructure Certification Program (NGICP)



Information Covered for GI Practices:

- ▶ Background information
 - ▶ What the GI practice is and how it functions
 - ▶ The components and materials used for the GI practice
- ▶ Construction
 - ▶ Sequence of construction
 - ▶ Typical/common problems – good/bad examples
- ▶ Inspection and Maintenance
 - ▶ What to look for – typical/common problems including good/bad examples
 - ▶ Types of corrective action to take

Stormwater Management Basics



What is stormwater?

- ▶ Water originating from rainfall or melting snow that runs off across the land instead of infiltrating into the ground
- ▶ Picks up pollutants (sediments, nutrients, metals) as it runs across paved and unpaved areas



Stormwater Management Basics



Why is it important to manage stormwater runoff?

- ▶ Runoff is a significant and growing problem
- ▶ Causes flooding
- ▶ Causes degraded water quality
- ▶ Impacts public health and safety

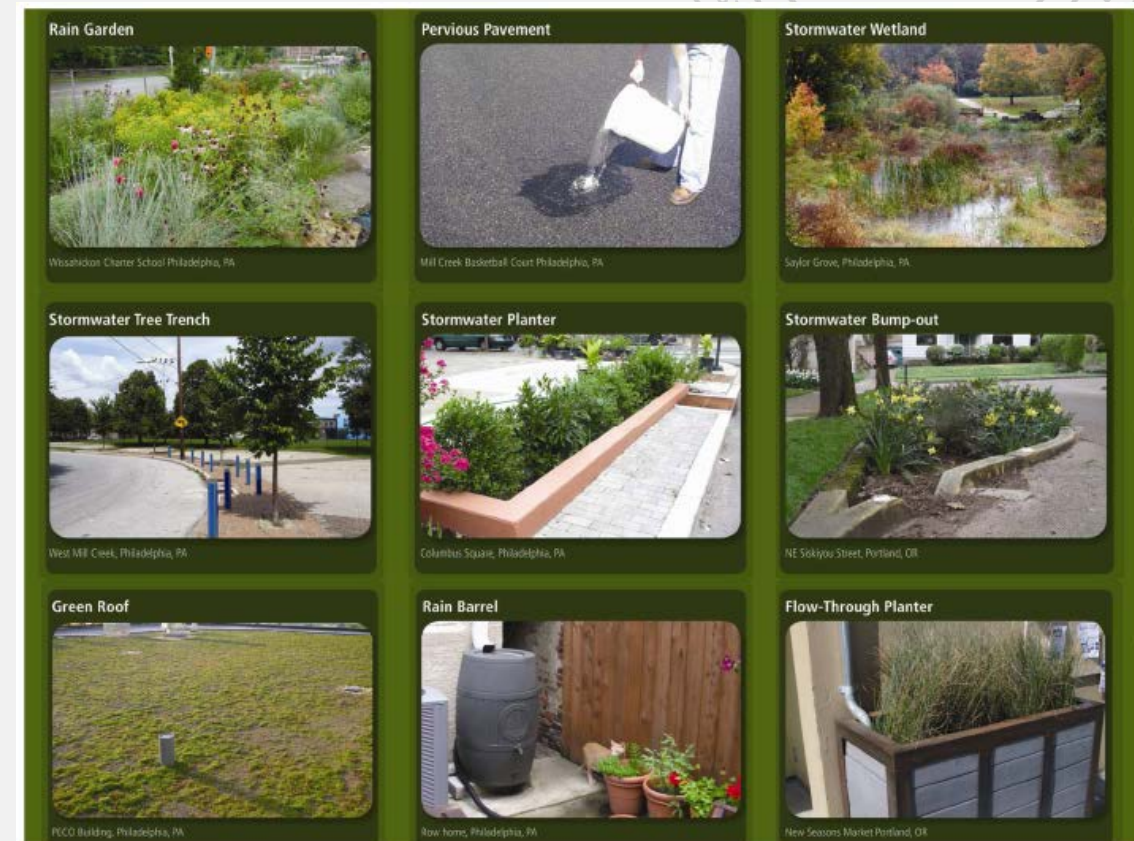


Stormwater Management Green Infrastructure



What is "Green Infrastructure"?

- ▶ Type of stormwater management
- ▶ Uses "retention" as well as "treatment" to address stormwater runoff
- ▶ Often times uses vegetation
- ▶ Examples:
 - ▶ Bioretention
 - ▶ Green roof
 - ▶ Permeable pavement



Stormwater Management Green Infrastructure



Why use "Green Infrastructure"?

- ▶ Attempts to restore hydrologic balance
- ▶ Reduces runoff (pollution prevention)
- ▶ Provides many other benefits:
 - ▶ Reduces heat in urban areas
 - ▶ Makes cities more resilient
 - ▶ Enhances property values



Stormwater Management Green Infrastructure



Common Terms:

- ▶ Impervious Surface – a hard, constructed surface such as rooftops, roadways, driveways, sidewalks, etc.
- ▶ Retention Practice – a stormwater practice that captures and retains runoff
- ▶ Infiltration Practice – a stormwater practice that captures runoff or precipitation and allows the water to soak into the ground
- ▶ Bioretention Facility – a shallow vegetated basin that treats runoff - also known as “rain garden” and micro-bioretention”
- ▶ Bioswale – a shallow vegetated open channel system that treats runoff – also known as a “water quality swale” or “grass swale”



MODULE 1

Introduction to Green Infrastructure



INTRODUCTION

Green Infrastructure (GI)



- ▶ Green infrastructure is an approach to stormwater management that protects, restores, or mimics the natural water cycle.



Bioretention



Porous Asphalt



Green Roof

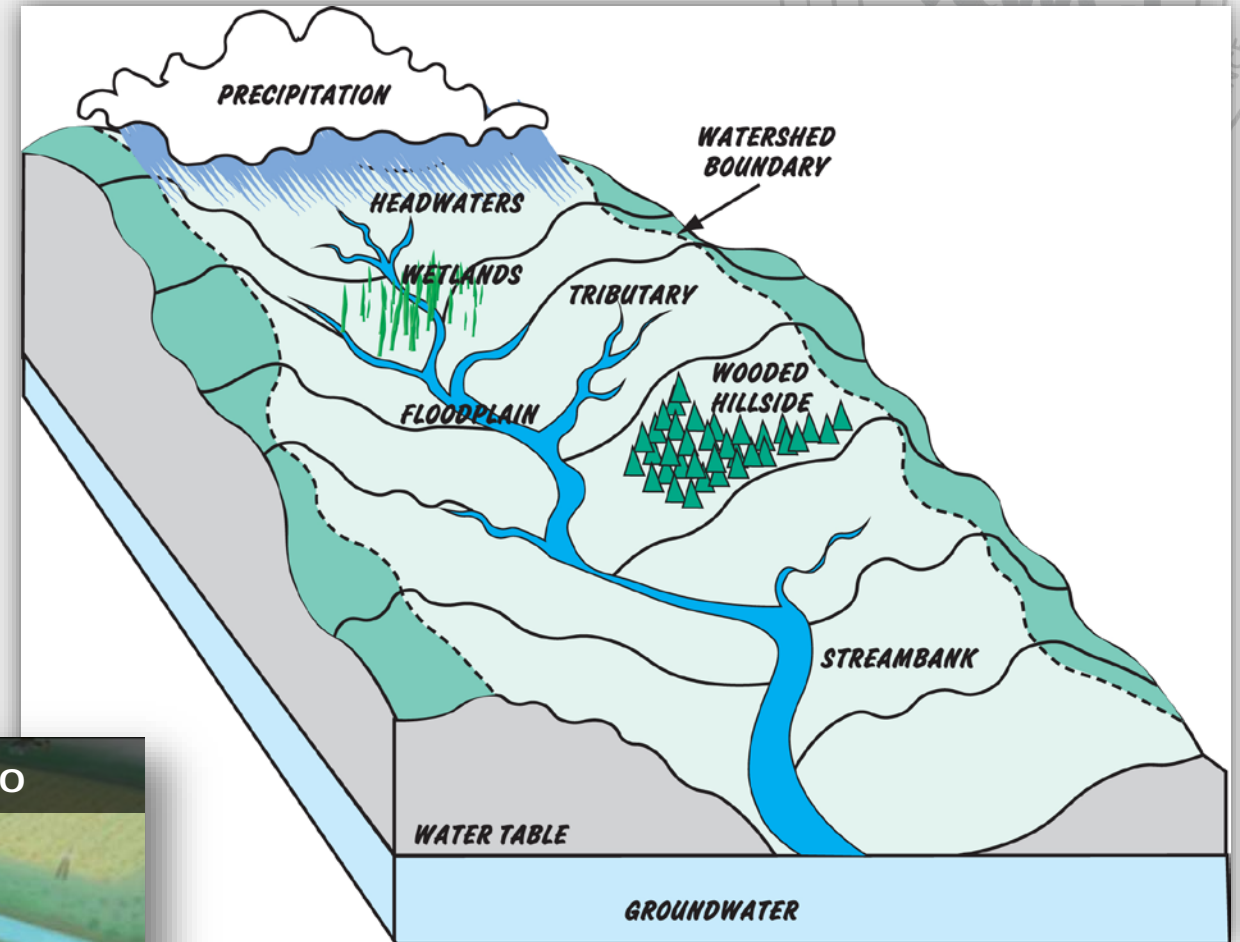
WATERSHED BASICS

Watershed



What is a watershed?

- ▶ A watershed is an area of land that drains all of the rainfall and streams to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. The word watershed is sometimes used interchangeably with drainage basin or catchment.



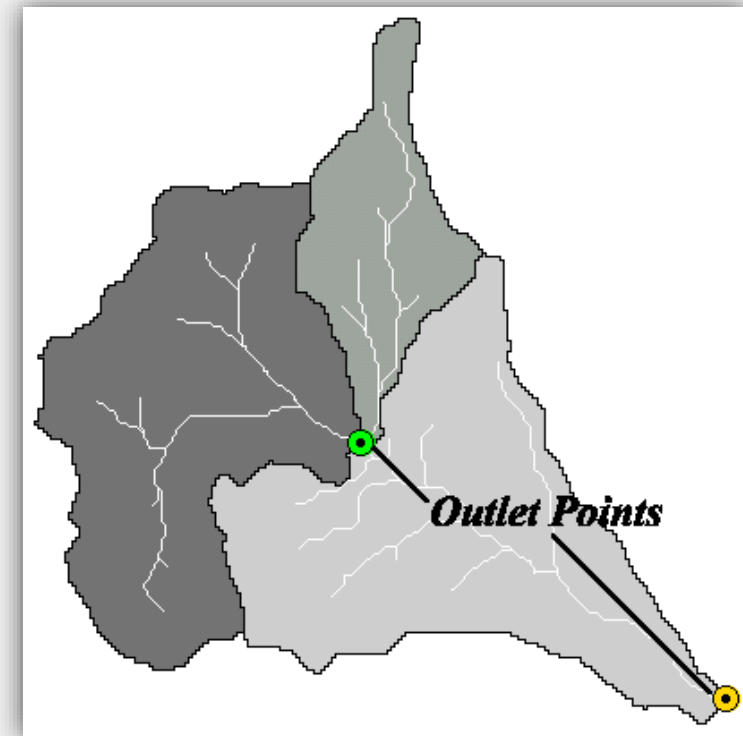
WATERSHED BASICS

Drainage Area



What is a drainage area?

- ▶ A drainage area (also called contributing area) is an area of land that drains to a specific point of interest either via surface runoff, open drainage ditch, or a piped system (catch basin, outfall, surface water, etc.).

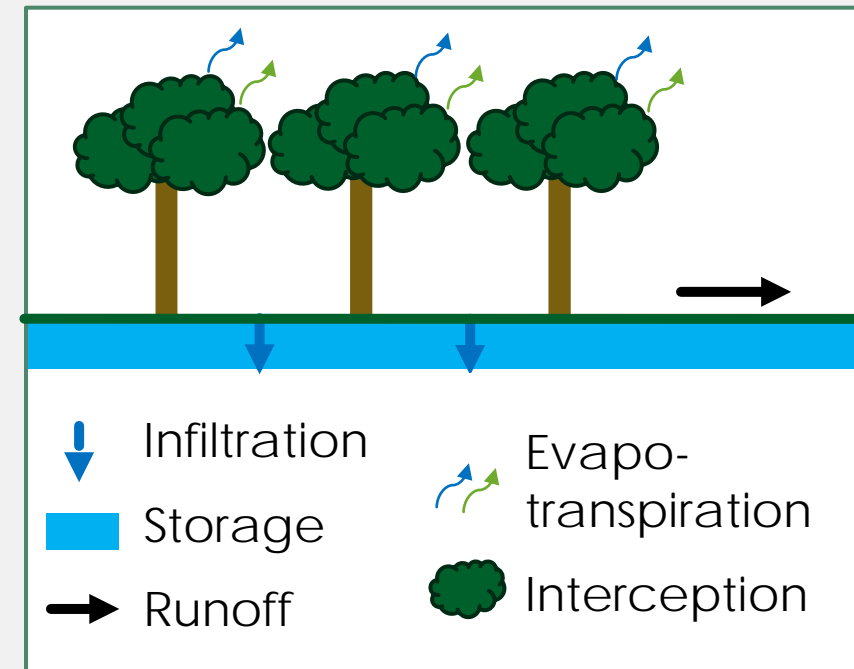


WATERSHED BASICS

Rainfall Pathways

What are the pathways for rainfall?

- ▶ Infiltration
- ▶ Storage
- ▶ Runoff
- ▶ Evapotranspiration
- ▶ Interception



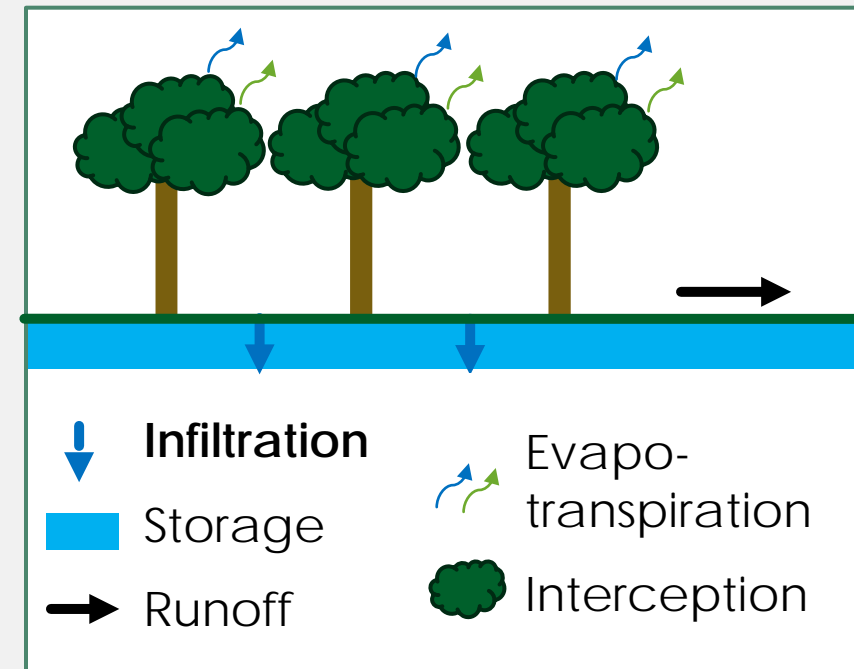
WATERSHED BASICS

Rainfall Pathways



What are the pathways for rainfall?

- ▶ Infiltration – the process by which water soaks into the soil.



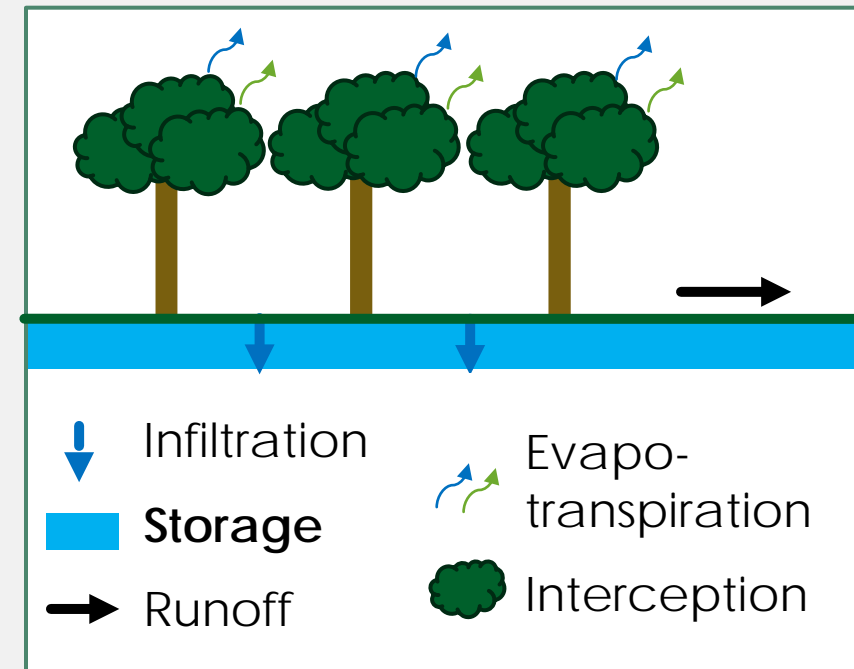
WATERSHED BASICS

Rainfall Pathways



What are the pathways for rainfall?

- ▶ Storage – water is held or locked up in its present state for a relatively long period of time. Short-term storage (days to weeks scale) occurs in surface water (rivers, creeks, ponds, lakes, reservoirs, canals, wetlands, etc.). Long-term storage (up to thousands of years) occurs in deep groundwater or ice caps (glaciers).



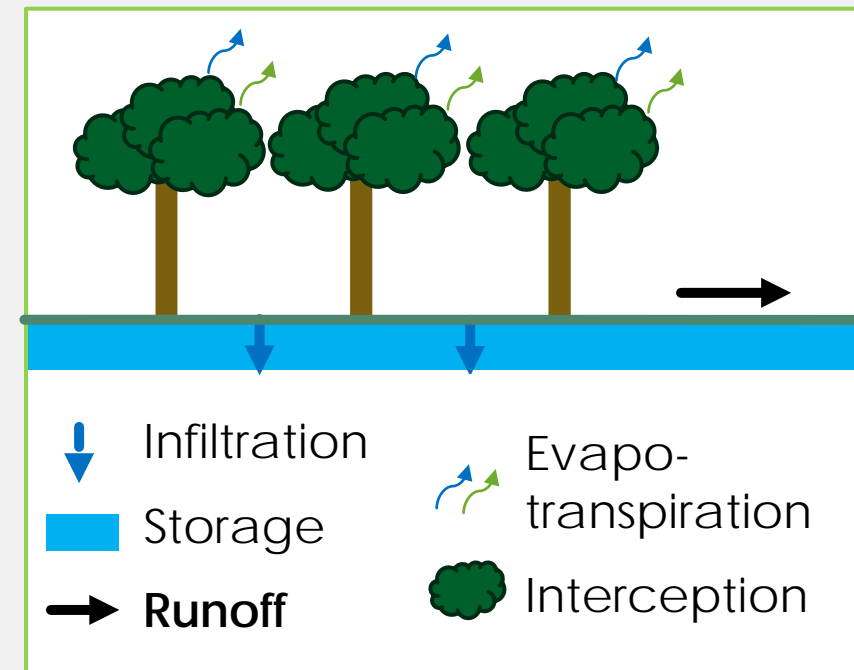
WATERSHED BASICS

Rainfall Pathways



What are the pathways for rainfall?

- ▶ Runoff – precipitation that hits saturated or impervious ground and begins to flow overland downhill.



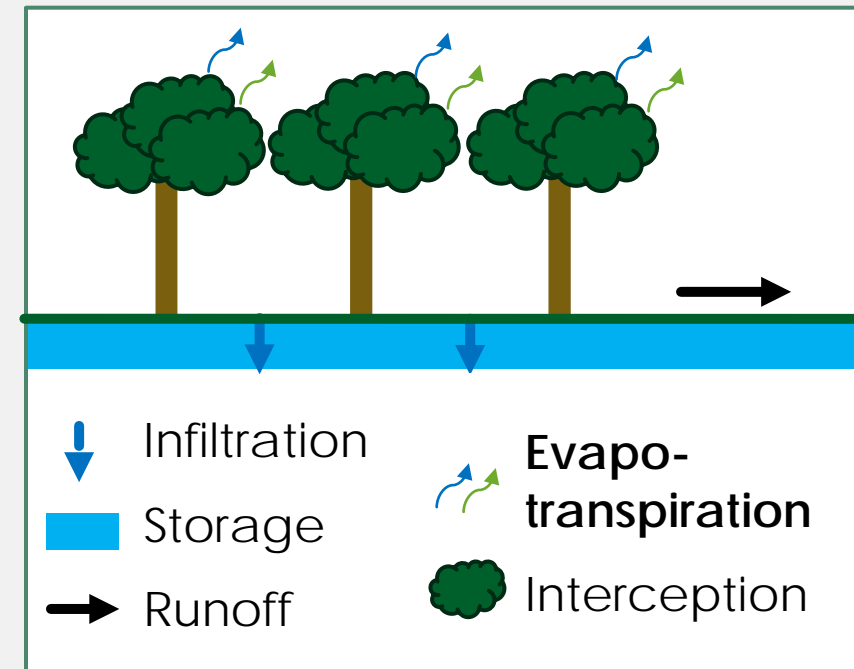
WATERSHED BASICS

Rainfall Pathways



What are the pathways for rainfall?

- ▶ Evapotranspiration – in general, this is the sum of evaporation and transpiration:
 - ▶ Evaporation – the process by which water changes from a liquid to a gas or vapor.
 - ▶ Transpiration – the release of water from plant leaves.



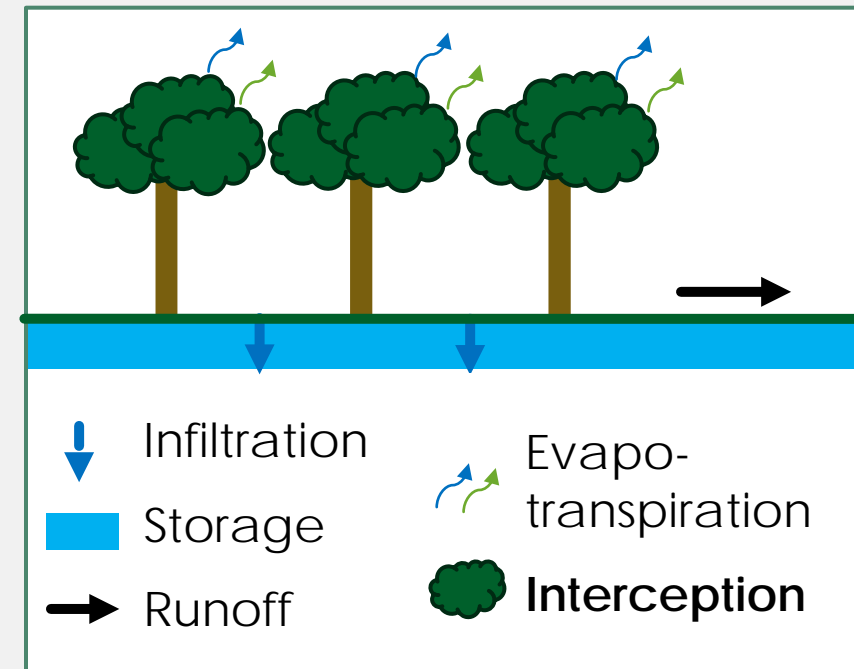
WATERSHED BASICS

Rainfall Pathways



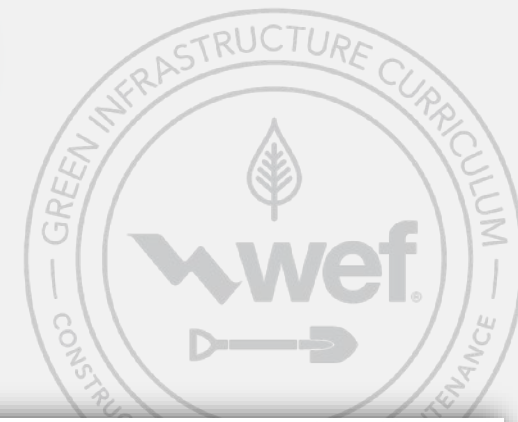
What are the pathways for rainfall?

- ▶ Interception – the process by which rainfall is caught and held by leaves, branches, etc.



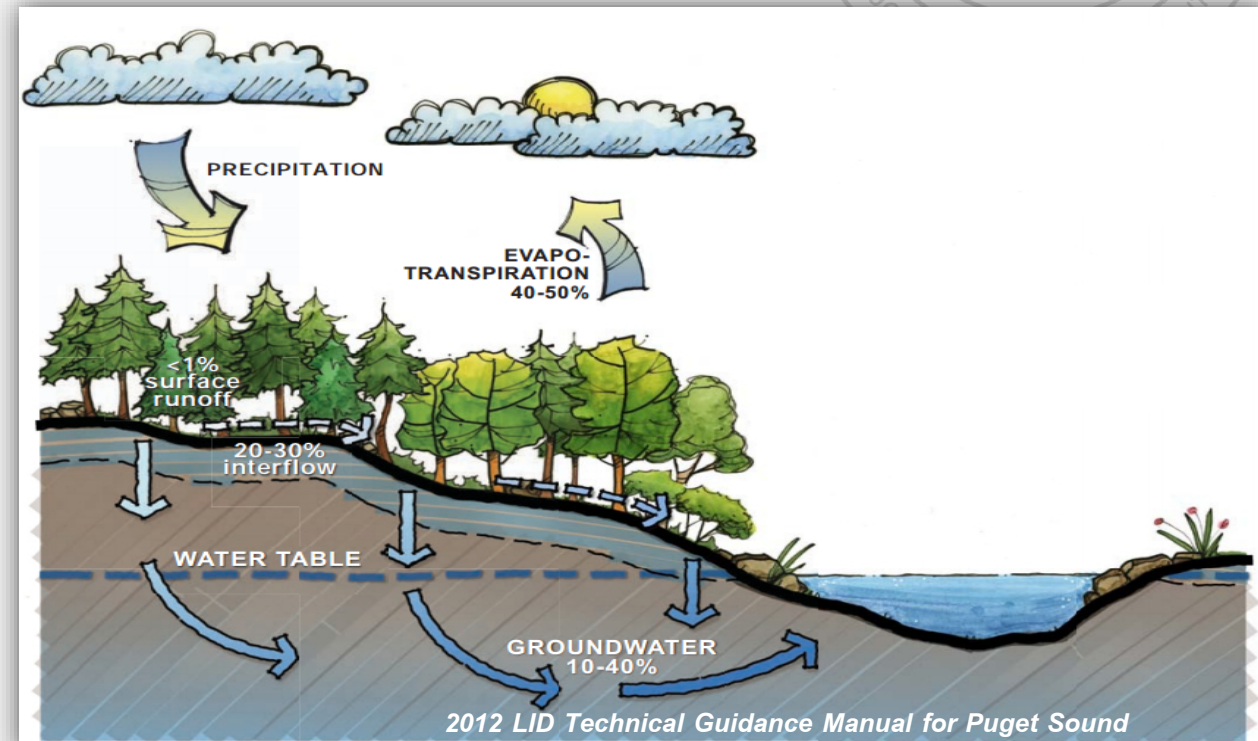
WATERSHED BASICS

Natural Water Cycle



Example: pre-developed water/hydrologic cycle in Pacific Northwest:

- ▶ During the winter, much of the rainfall is intercepted by the forest canopy and evaporated.
- ▶ The overland flow component is $<1\%$ and could take hours, days, or weeks to reach a surface water.
- ▶ During the summer and fall, streams are maintained by snowmelt, glacial melt water and/or groundwater.



The goal of Green Infrastructure is to mimic natural hydrologic processes.

STORMWATER MANAGEMENT

Stormwater



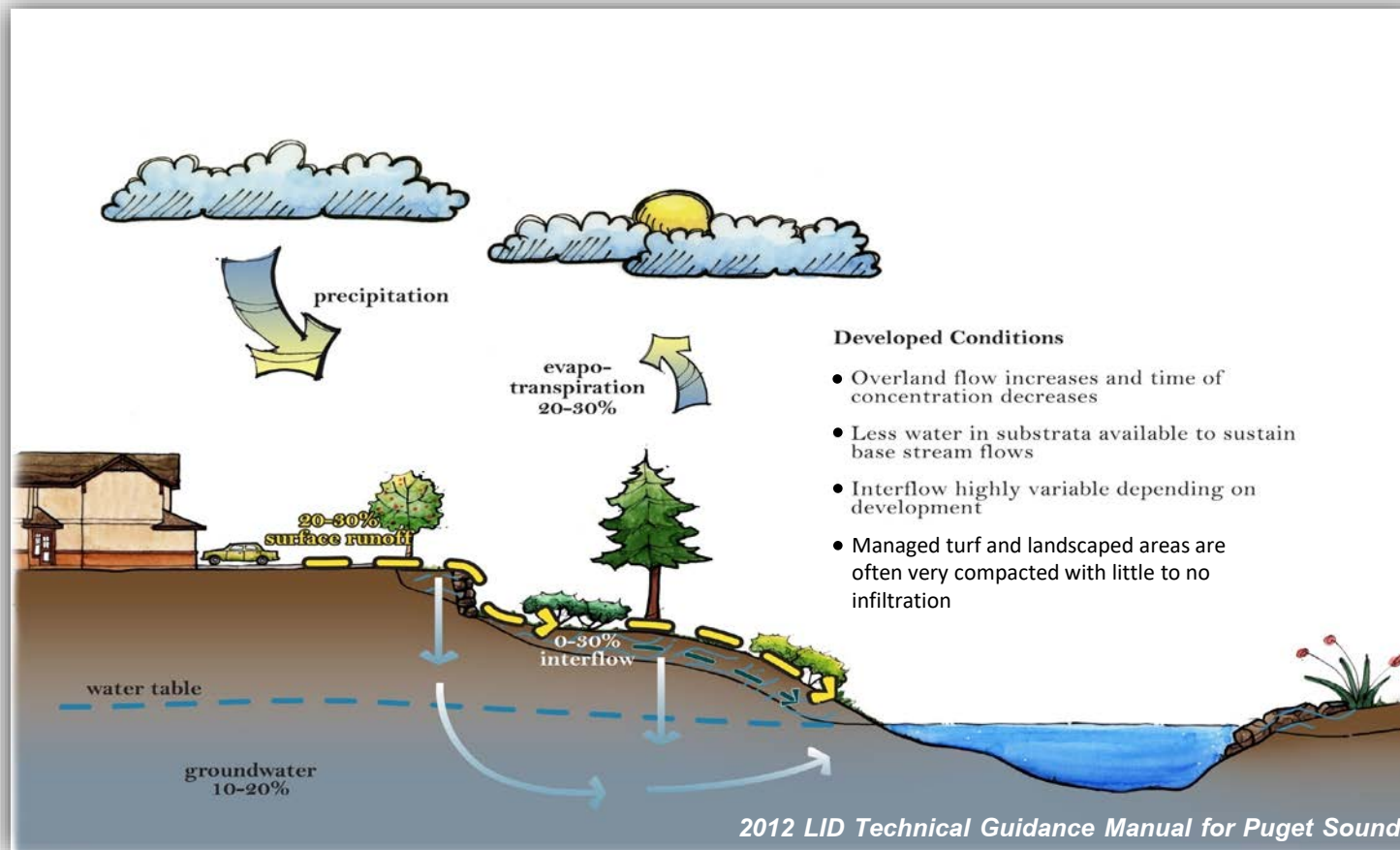
What is stormwater?

- ▶ Water originating from rainfall or melting snow that runs off across the land instead of infiltrating into the ground
- ▶ Picks up pollutants (sediment, nutrients, metals) as it runs across paved and unpaved areas



INTRODUCTION

Urban Water Cycle



APPROACHES TO SW MANAGEMENT Subtopics



Ponds & Vaults



Grey Infrastructure



Green Infrastructure



APPROACHES FOR SW MANAGEMENT

Green Infrastructure



Stormwater management practices that protect, restore, and mimic the native hydrologic condition by providing the following functions:

- ▶ Infiltration
- ▶ Filtration
- ▶ Storage
- ▶ Evaporation
- ▶ Transpiration



APPROACHES FOR SW MANAGEMENT

Green Infrastructure



Environmental benefits:

- ▶ Water quality treatment
- ▶ Flow control
- ▶ Habitat
- ▶ Aesthetics
- ▶ Cooling (reduces heat island effect)





MODULE 2

Common GI Construction Materials

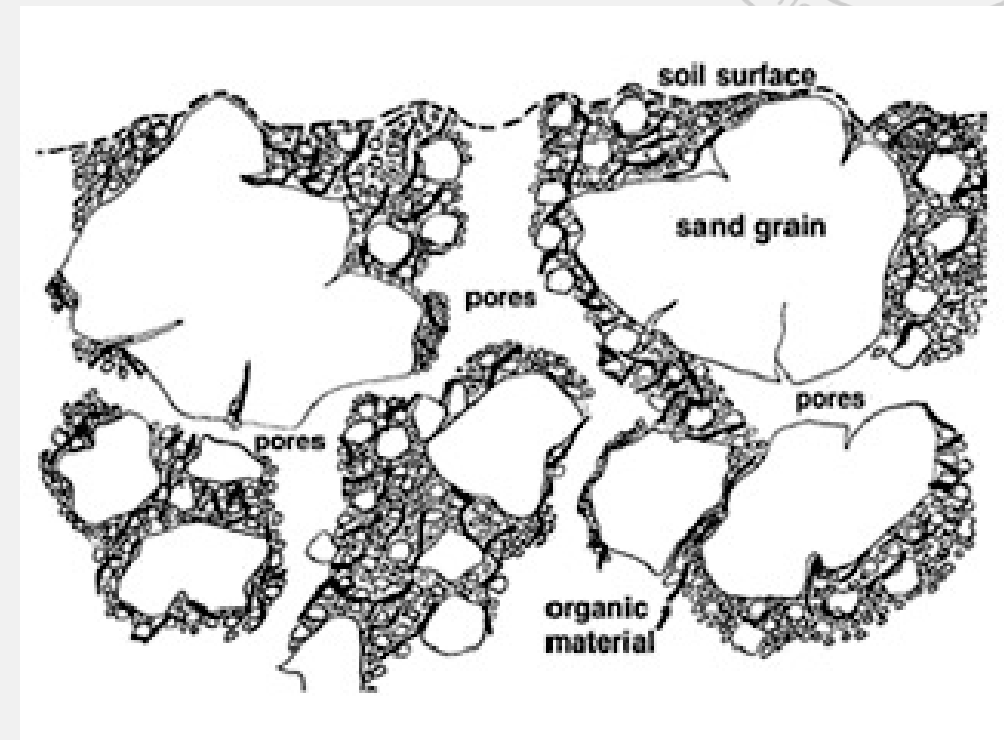


SOILS AND AGGREGATES

Pore Space

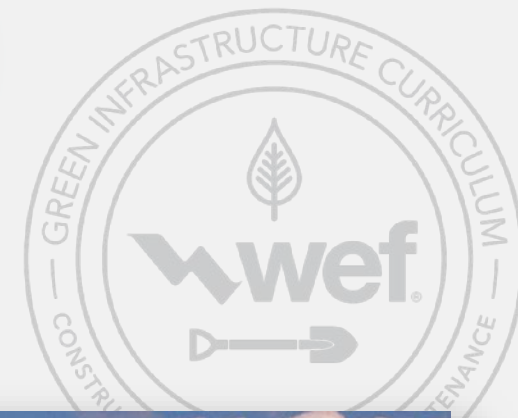


- ▶ Air spaces between aggregates
- ▶ Necessary for water storage, oxygen and organisms living in the soil
- ▶ Necessary for infiltration through soil, aggregate or permeable pavement (arrangement of pores is important)
- ▶ Larger pore spaces in larger aggregates, but similar pore volume in finer and coarser aggregates
- ▶ Finer pores increase water holding over time (field capacity) and may improve plant survival over time



SOILS AND AGGREGATES

Compaction



- ▶ Loss of pore space in soil and aggregates
- ▶ Preventing over-compaction a primary concern for construction and maintenance of infiltrating GI facilities
- ▶ Compaction can be deep (2-3 feet)
 - ▶ Caused by heavy equipment on wet soils
 - ▶ Difficult to fix
- ▶ Usually measured in the field with a nuclear density gauge or observations of a geotechnical engineer
- ▶ Measured in lab by determining density of a sample with a specific moisture content and a specific pressure applied to that sample in a cylinder



SOILS AND AGGREGATES

Top Soil

What is top soil?

- ▶ Upper layer of soil where most organic matter is incorporated, most nutrients are available and most root development occurs
- ▶ Amount used may vary by site and development type (i.e., less topsoil generally available for retrofit or redevelopment projects than a greenfield project)



SOILS AND AGGREGATES

Compost



What is compost?

- ▶ Product resulting from controlled biological decomposition of organic waste
- ▶ Adds active biological material to media mix
- ▶ Can enhance pollutant processing, support vegetation and stabilize soils
- ▶ Organic waste typically yard trimmings and food waste
 - ▶ May contain other materials (e.g., wood chips, manure, biosolids, etc. mixed in at compost facilities)
 - ▶ Some locations may specific mix



SOILS AND AGGREGATES

Sand

What is sand?

- ▶ Mineral aggregate ranging in size from 0.0625 mm to 2 mm



SOILS AND AGGREGATES

Washed Uniform Stone (AASHTO #57)



What is washed, uniform stone?

- ▶ Washed to remove finer particle sizes
- ▶ Uniform = generally same particle size = poorly graded
- ▶ Also referred to as “gravel” in some states



Source: www.bradserfarms.com

SOILS AND AGGREGATES

Washed Uniform Stone (AASHTO #57)



What are its characteristics?

- ▶ AASTHO spec (primarily passing 1 ½ and 1" screens)
- ▶ See gradation specification
- ▶ Very low fines (passing 200 sieve) content
- ▶ #57 is a crushed stone = angular = important for creating structural support



Source: Capitol Flexi-Pave

SOILS AND AGGREGATES

Rip Rap

What is rip rap?

- ▶ A mixture of rock types, commonly granite or limestone
- ▶ Sometimes can include concrete rubble from building and paving demolition
- ▶ Also commonly known as shot rock, rock armor, or rubble
- ▶ Commonly used to armor shorelines, streambeds, bridge abutments, pilings, and other shoreline structures
- ▶ Also commonly used for erosion control
- ▶ Readily available in most areas



COMPACTION TESTING

- ▶ The designer (usually a geotechnical or civil engineer) determines the appropriate compaction standard.
- ▶ Visual inspection by a geotechnical inspector to determine “firm and unyielding” or testing using modified proctor results and a nuclear density gauge may be required.
- ▶ Nuclear density gauge measurement is not appropriate for larger, open-graded aggregate base structures such as those under permeable pavement systems.



Source: Geoengineer

OTHER MATERIALS

Geotextile Fabric



What is the purpose of geotextile fabrics?

- ▶ Separation layer to prevent clogging by migration of fine material into infiltration systems
- ▶ Separation layer to prevent destabilization of adjacent structures by migration of fine material into coarser material (e.g., permeable pavement aggregate base)
- ▶ Strength across inconsistent and/or weak soils
- ▶ Can be a layer that clogs if used in wrong application or if geotextile is wrong material for the soil or media composition
- ▶ Can be over used and often not needed for many GI applications
- ▶ Can be referred to by other names, such as geofabric, geotextile, or geosynthetic material/fabric

OTHER MATERIALS

Waterproofing Membranes



What is a waterproofing membrane?

- ▶ Thin sheet of synthetic material that does not allow water to pass through it
- ▶ Green or blue roofs - waterproofing membrane is fastened or adhered to a roof deck
 - ▶ Creates a water barrier
 - ▶ Protects underlying roof structure
- ▶ Urban areas (where infiltration structures are installed below grade next to a building)
 - ▶ Waterproofing membrane installed on building foundation to prevent moisture and water from entering building basement





MODULE 3

Vegetation in Green Infrastructure



PURPOSE OF VEGETATION IN GI



- ▶ Maintain and improve infiltration in soil/media for flow control and treatment facilities
- ▶ Promote healthy population of soil organisms
- ▶ Enhanced wildlife habitat
- ▶ Slow runoff velocities
- ▶ Establish a biological system which functions to remove pollutants and provide other environmental benefits
- ▶ Nutrient and other contaminant uptake
- ▶ Prevent erosion
- ▶ Visual buffering of roads and other infrastructure
- ▶ Aesthetics in the urban landscape



PURPOSE OF VEGETATION IN GI

Examples



PURPOSE OF VEGETATION IN GI

Common Vegetation in GI



Trees

American Hornbeam (*Carpinus caroliniana*)
Bald cypress (*Taxodium distichum*)
Birch (*Betula lenta*, *Betula nigra*)
Black gum (*Nyssa sylvatica*)
Black willow (*Salix nigra*)
Hemlock (*Tsuga canadensis*)
Pin oak (*Quercus palustris*)
Red maple (*Acer rubrum*)
Serviceberry (*Amelanchier arborea/canadensis/laevis*)
Swamp white oak (*Quercus bicolor*)
Sweetbay Magnolia (*Magnolia virginiana*)
Sweet gum (*Liquidambar styraciflua*)
Sycamore (*Platanus occidentalis*)

Perennials and Ferns

Blazing star (*Liatris spicata*)
Blue flag iris (*Iris versicolor*)
Blue vervain (*Verbena hastata*)
Boneset (*Eupatorium perfoliatum*)
Bottle gentian (*Gentiana andrewsii*)
Cardinal flower (*Lobelia cardinalis*)
Cinnamon fern (*Osmunda cinnamomea*)
Culver's root (*Veronicastrum virginicum*)
Golden ragwort (*Packera aurea*)
Goldenrod (*Solidago patula*, *S. rugosa*)
Great blue lobelia (*Lobelia siphilitica*)
Green bullrush (*Scirpus atrovirens*)
Ironweed (*Vernonia noveboracensis*)

Shrubs

Bayberry (*Morella pensylvanica*)
Black chokeberry (*Aronia melanocarpa*)
Bottlebrush Buckeye (*Aesculus parviflora*)
Buttonbush (*Cephalanthus occidentalis*)
Elderberry (*Sambucus canadensis*)
Inkberry (*Ilex glabra*)
Ninebark (*Physocarpus opulifolius*)
Possumhaw (*Viburnum nudum*)
Red-osier Dogwood (*Cornus sericea*)
Red Chokeberry (*Aronia arbutifolia*)

TREES

Examples



Bioswale



Stormwater Wetlands



Green Roof



Tree Trench



Bioretention Planter



SOIL AND GROWING MEDIA

Most media requirements of GI facilities involve balancing competing needs including high infiltration rates and filtering nutrients while growing plants.



Bioretention requires materials with:

- The ability to conform to local codes and specifications.
- High infiltration rates that require minimal fine particles (e.g., clean sands or gravel).
- Moderate to low nutrient levels to prevent flushing of nutrients.
- High water holding capacity.
- A good substrate for healthy soil biota.

Green roofs require materials with:

- High infiltration rates that require minimal fine particles (e.g., clean sands or gravel).
- Moderate to low nutrient levels to prevent flushing of nutrients.
- High water holding capacity.
- Low levels of organic matter and less emphasis on well-developed media biota.
- Low density (lightweight).

Tree trenches require materials with:

- Moderate infiltration rates.
- Moderate to low nutrient levels to prevent flushing of nutrients.
- High water holding capacity.
- A good substrate for healthy soil biota.
 - Tree trenches often require specific types of topsoil.

TRANSPORTING AND STORING VEGETATION



- ▶ Damage to plants can occur during any step of the handling, transport, storage, and installation process.
- ▶ Any damage that plants sustain may affect their long-term health and survival.
- ▶ Following the best management practices within each step of the process will help improve the success of plant establishment and long-term health.



PLANT ESTABLISHMENT & MAINTENANCE

General factors that affect establishment



- ▶ Select the right plant for the right place.
- ▶ Plant high quality vegetation.
- ▶ Utilize proper timing for planting.
- ▶ Mulch to regulate soil moisture and temperature.
- ▶ Utilize an appropriate watering schedule especially for first 1-3 years.
- ▶ Install adequate barriers to prevent soil compaction from foot traffic or vehicles.

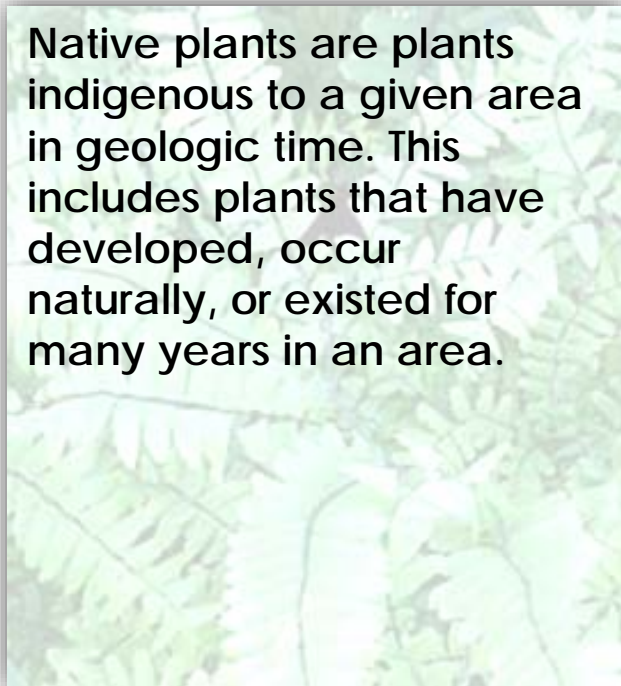
PLANT ESTABLISHMENT & MAINTENANCE

Definitions



Native Plants

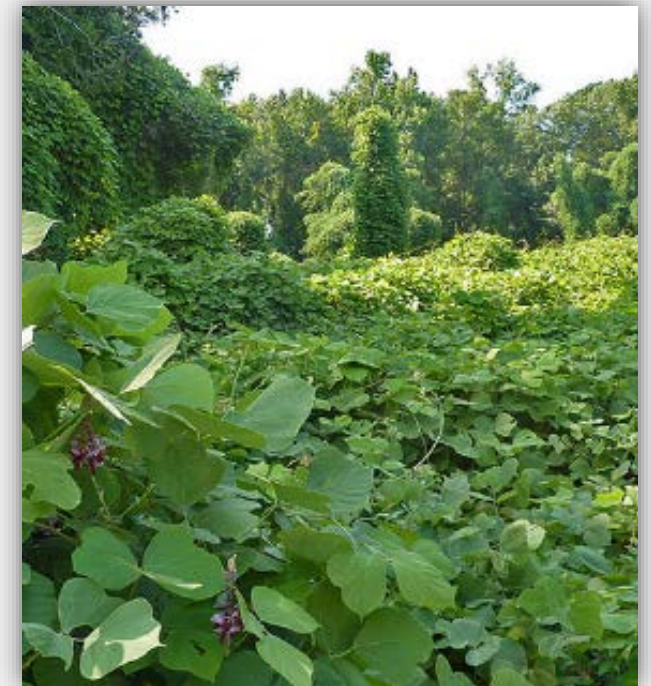
Native plants are plants indigenous to a given area in geologic time. This includes plants that have developed, occur naturally, or existed for many years in an area.



Weeds



Invasive Species



PLANT ESTABLISHMENT & MAINTENANCE

Definitions

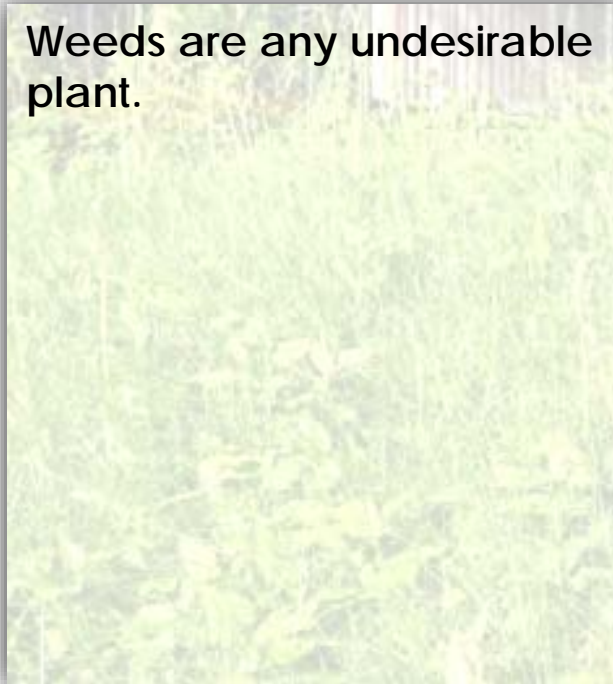


Native Plants

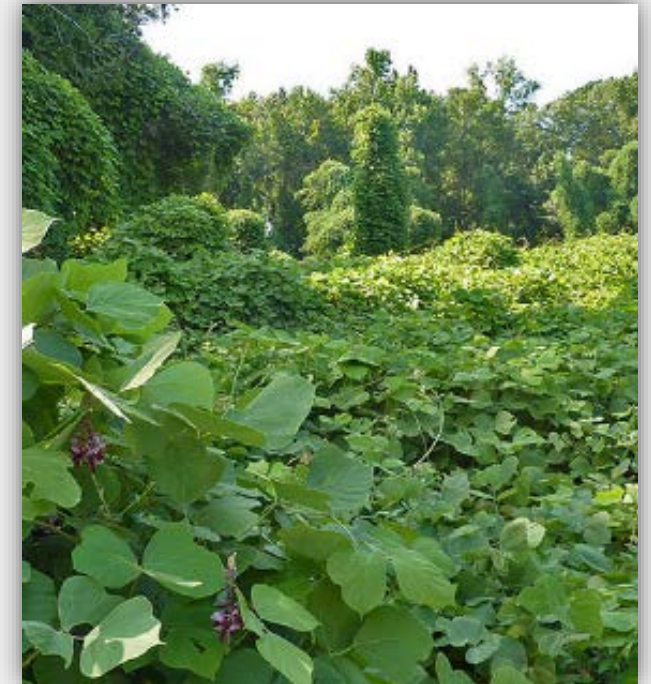


Weeds

Weeds are any undesirable plant.



Invasive Species



PLANT ESTABLISHMENT & MAINTENANCE

Definitions



Native Plants

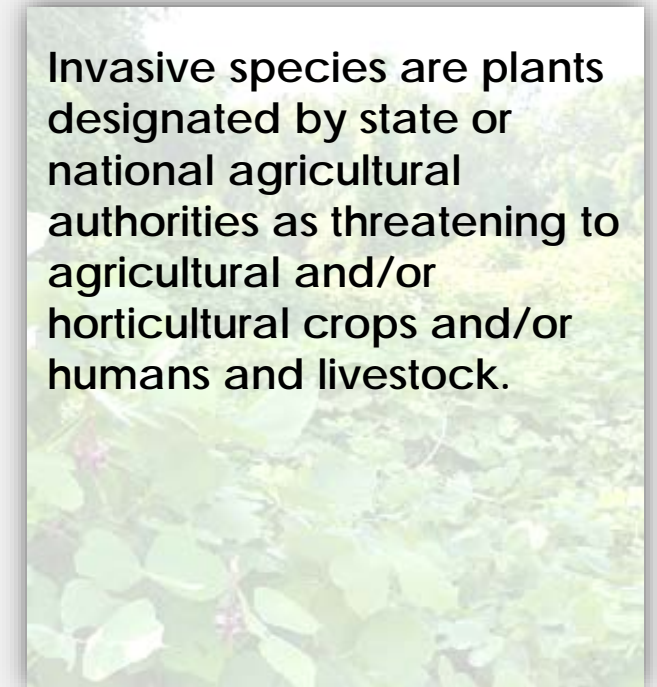


Weeds



Invasive Species

Invasive species are plants designated by state or national agricultural authorities as threatening to agricultural and/or horticultural crops and/or humans and livestock.





MODULE 4

Safety In and Around GI Sites



OVERVIEW

- ▶ Personal protective equipment (PPE) for GI construction and maintenance activities
 - ▶ Hard hats
 - ▶ High-visibility vests
 - ▶ Eye protection (safety glasses, face shields)
 - ▶ Long sleeves and pants
 - ▶ Gloves
 - ▶ Foot protection
 - ▶ Ear protection (earplugs)
- ▶ Additional safety information can be found on the Occupational Safety and Health Administration (OSHA) website: www.osha.gov



UTILITIES

Identifying and Interpreting

- ▶ Nationwide “Call Before You Dig” program.
- ▶ Federally designated number (811) will route you to the one call center in your state.
- ▶ Some states also have web ticket entry programs on the call811.com website.
- ▶ General rule of thumb - avoid digging within 18-24 inches of marked utilities.
 - ▶ This varies depending on state law.



UTILITIES

Identifying and Interpreting



- ▶ American Public Works Association (APWA) uniform color code for marking underground utilities.

White	PROPOSED EXCAVATION
Fluorescent Pink	TEMPORARY SURVEY MARKINGS
Red	ELECTRIC POWER LINES, CABLES, CONDUIT AND LIGHTING CABLES
Yellow	GAS, OIL, STEAM, PETROLEUM OR GASEOUS MATERIALS
Orange	COMMUNICATION, ALARM OR SIGNAL LINES, CABLES OR CONDUIT
Blue	POTABLE WATER
Purple	RECLAIMED WATER, IRRIGATION AND SLURRY LINES
Green	SEWERS AND DRAIN LINES

UTILITIES

Overhead Power



- ▶ Electrical hazards can cause:
 - ▶ Burns
 - ▶ Shocks
 - ▶ Electrocutions
- ▶ Approximately 350 electrical-related fatalities occur each year.
- ▶ OSHA Electrical Safety Quick Card
 - ▶ https://www.osha.gov/OshDoc/data/Hurricane_Facts/electrical_safety.pdf



UTILITIES

Underground Power

- ▶ Damage to and contact with underground electrical lines can cause:
 - ▶ Burns
 - ▶ Shocks
 - ▶ Electrocutions
- ▶ OSHA Electrical Safety Quick Card
 - ▶ https://www.osha.gov/OshDoc/data_Hurricane_Facts/electrical_safety.pdf



UTILITIES

Underground Gas

- ▶ Explosion is the greatest hazard associated with underground gas lines.
- ▶ Built up natural gas is extremely volatile.



UTILITIES

Force Mains—Water or Sewer



Water and sewer main hazards:

- ▶ Force mains are under pressure and can result in flooding, roadway and property damage, and sinkholes.
- ▶ Sewer line breaks can be a human health hazard.



ADJACENT ROADWAY AND VEHICLE TRAFFIC

Bystander/pedestrian, private vehicle, construction inspection and maintenance hazards:

- ▶ Being struck by work vehicles and equipment from construction and maintenance activities
- ▶ Flying debris and dust from construction and maintenance activities
- ▶ Being struck by motorists driving near the job site
- ▶ Car exhaust and other toxic fumes from adjacent traffic
- ▶ Loud noises



SLIPS, TRIPS, AND FALLS



Definitions

- ▶ **Slip**: Occurs when too little friction or traction between feet and walking/working surface, resulting in a loss of balance.
- ▶ **Trip**: Occurs when foot or lower leg hits an object and the upper body continues moving, resulting in a loss of balance; also, stepping down to a lower surface and losing balance.
- ▶ **Fall**: Occurs when the body is too far off center of balance.
 - ▶ Falls can occur at the same level or to a lower level.



CONFINED SPACES



Definition (29 CFR 1910.146)

- ▶ **Confined Space**: A confined space has limited openings for entry or exit, is large enough for entering and working, and is not designed for continuous worker occupancy.
- ▶ Confined spaces include underground vaults, tanks, storage bins, manholes, pits, silos, underground utility vaults and pipelines.
- ▶ OSHA Confined Space Quick Card:
https://www.osha.gov/OshDoc/data_Hurricane_Facts/confined_space_permit.pdf



CONFINED SPACES



Potential hazards:

- ▶ Potentially hazardous atmosphere – hydrogen sulfide, low oxygen, etc.
- ▶ Walls that converge inward or floors that slope downward and taper into a smaller area which could trap an entrant
- ▶ Potentially serious physical hazards such as unguarded machines or exposed live wires



ANIMALS AND PESTS

Stinging and Biting Insects



Insects, Spiders, and Ticks:

- ▶ Wear long pants, socks, and long-sleeve shirts.
- ▶ Use insect repellents that contain DEET or Picaridin.
- ▶ Treat bites and stings with over-the-counter products that relieve pain and prevent infection.
- ▶ Be aware of local/regional venomous or dangerous animals. Examples include fire ants and black widows.
 - ▶ Avoid fire ants; their bites are painful and cause blisters.
 - ▶ Severe reactions to fire ant bites (chest pain, nausea, sweating, loss of breath, serious swelling or slurred speech) require immediate medical treatment.
 - ▶ Black widow bite symptoms include muscle cramps, chills, fever, vomiting, sweating, headaches, and severe high blood pressure.
- ▶ Any allergies or medical conditions that require the use of an epiPen in the event of an insect sting or other vector should be noted by fellow workers along with appropriate first aid steps and materials.



EXCAVATION AND TRENCHING



- ▶ Potential hazards
 - ▶ Placing equipment too close to structures can threaten structural integrity. Equipment vibrations, adverse weather conditions, and ground water can change the condition and classification of the soil.
 - ▶ Piling soil and placing equipment too close to the vertical walls of the trench increase the likelihood of collapse.
 - ▶ One cubic yard of soil can weigh as much as a car.
- ▶ Two workers are killed every month in trench collapses.
- ▶ OSHA Working Safely in Trenches Quick Card:
https://www.osha.gov/Publications/trench/trench_safety_tips_card.pdf



EXCAVATION AND TRENCHING



- ▶ Safety Precautions:
 - ▶ Divert water away from open trenches and inspect trench walls after every rainstorm.
 - ▶ Water erodes and changes soil, often weakening the stability of the soil.
- ▶ Protective systems must be used when the excavation is 4 feet or more in depth.
- ▶ Cave-in protection is not required when excavations are made entirely in stable rock, excavations are less than 4 feet deep, or examination by a competent person provides no indication of a potential cave-in.



HEAT STRESS



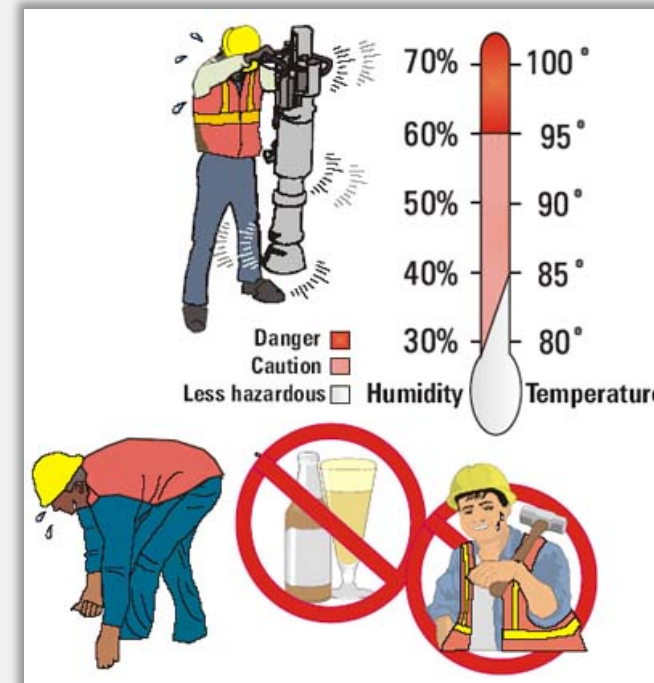
- ▶ Types of heat stress:
 - ▶ Heat exhaustion
 - ▶ Heat stroke (most serious illness)
- ▶ Risk factors:
 - ▶ High temperature and humidity, direct sun exposure, no breeze or wind
 - ▶ Low liquid intake
 - ▶ Heavy physical labor
 - ▶ Waterproof clothing
 - ▶ No recent exposure to hot workplaces
- ▶ OSHA Heat Stress Quick Card:
<https://www.osha.gov/Publications/osha3154.pdf>



HEAT STRESS



- ▶ Symptoms of Heat Exhaustion:
 - ▶ Headache, dizziness, or fainting
 - ▶ Weakness and wet skin
 - ▶ Irritability or confusion
 - ▶ Thirst, nausea, or vomiting
- ▶ Symptoms of Heat Stroke:
 - ▶ Confusion, inability to think clearly, passing out, collapsing, or having seizures (fits)
 - ▶ Sweating stops



COLD STRESS

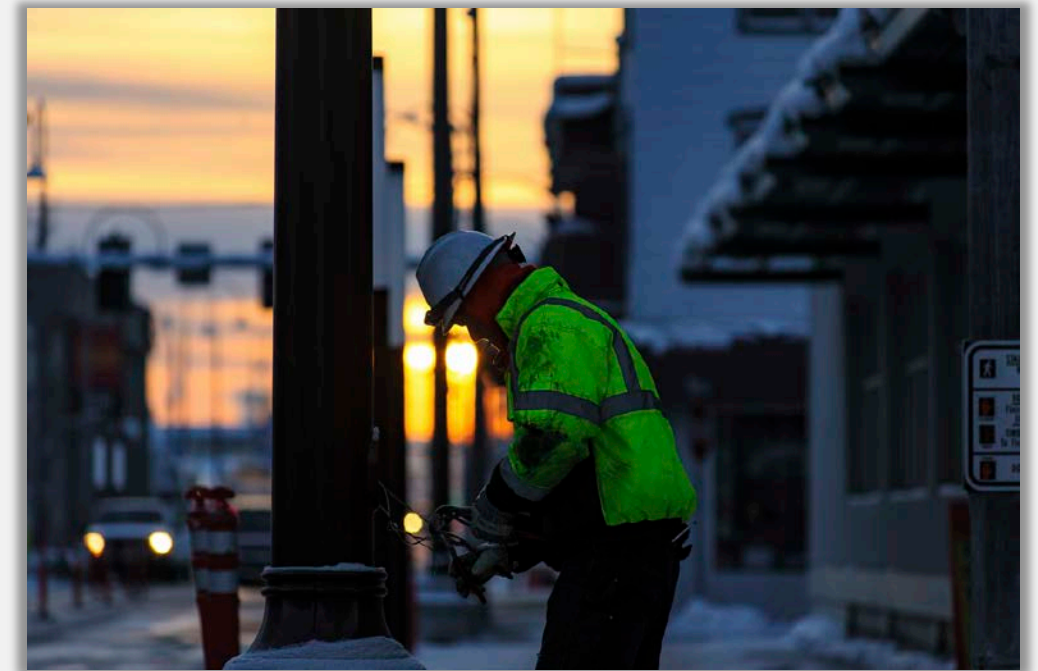


- ▶ Types of cold stress:
 - ▶ Hypothermia: body temperature 95°F or less
 - ▶ Frostbite: body tissues freeze (e.g., hands and feet)
 - ▶ Can occur at temperatures above freezing (wind chill)
 - ▶ May result in amputation
 - ▶ Trench foot (immersion foot): non-freezing injury to the foot
 - ▶ Caused by lengthy exposure to wet and cold
 - ▶ Can occur at temperatures as high as 60°F (if feet are constantly wet)
- ▶ Risk factors:
 - ▶ Dressing improperly
 - ▶ Wet clothing or skin
 - ▶ Exhaustion
- ▶ OSHA Cold Stress Quick Card:
<https://www.osha.gov/Publications/OSHA3156.pdf>



COLD STRESS

- ▶ Symptoms of hypothermia
 - ▶ Mild Symptoms: alert but shivering
 - ▶ Moderate to Severe Symptoms: shivering stops; confusion; slurred speech; heart rate/breathing slow; loss of consciousness; death
- ▶ Symptoms of frostbite
 - ▶ Numbness
 - ▶ Reddened skin develops gray/white patches
 - ▶ Feels firm/hard
 - ▶ May blister
- ▶ Symptoms of trench foot (immersion foot)
 - ▶ Redness
 - ▶ Swelling
 - ▶ Numbness
 - ▶ Blisters





MODULE 5

Green Infrastructure Site Management



OVERVIEW

Site Management Basics - Construction Documents



- ▶ Construction documents consist of:
 - ▶ Site plans – “What to Build”
 - ▶ Graphical description of a construction site and elements of a site
 - ▶ Specifications (“Specs”) – “How to Build It”
 - ▶ Written detailed information on materials used on a construction project as well as the proper technique required for installation/construction



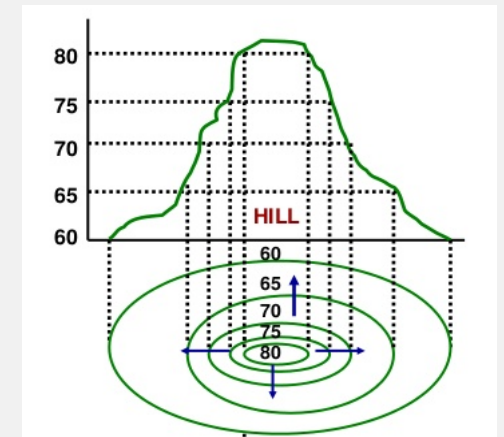
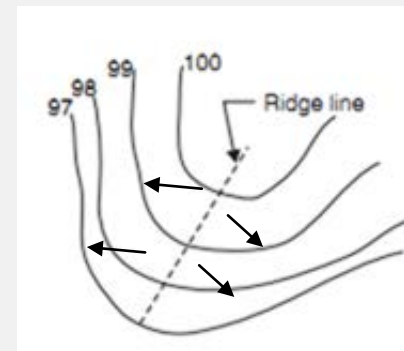
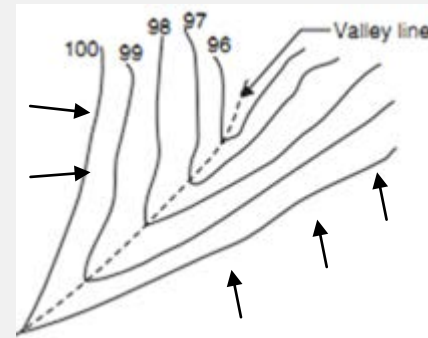
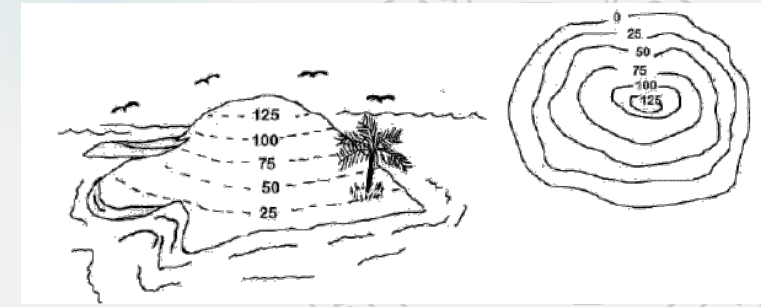
123rf.com, 2016

OVERVIEW

Site Management Basics

Contours

- ▶ Contour lines:
 - ▶ Lines representing equal elevation
 - ▶ Grading plan: two-dimensional document that represents three-dimensional world
- ▶ Ridge line:
 - ▶ Boundary line where water flows in different directions
- ▶ Valley line:
 - ▶ Line where water collects



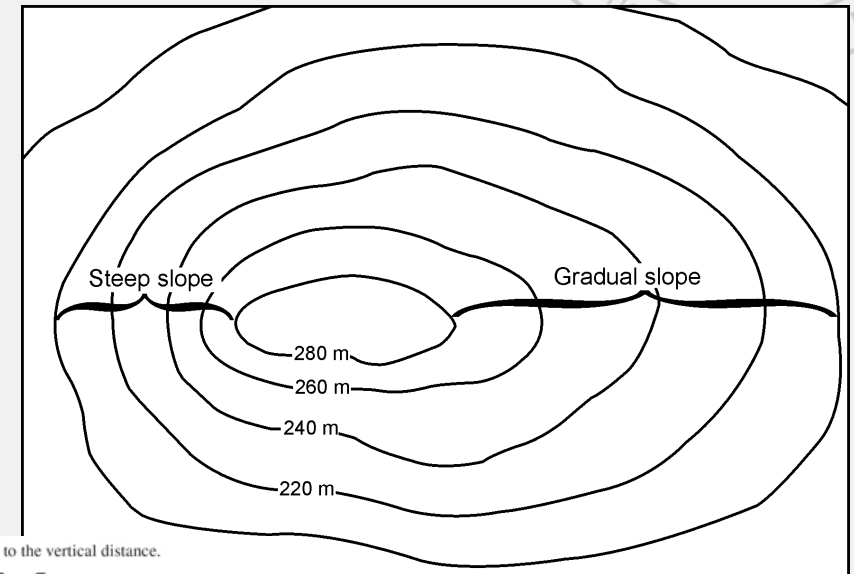
123rf.com, 2016

OVERVIEW

Site Management Basics - Slopes

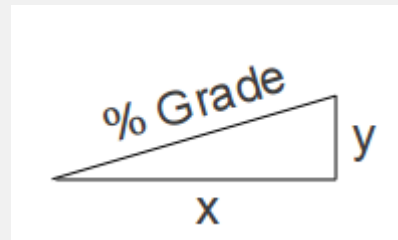
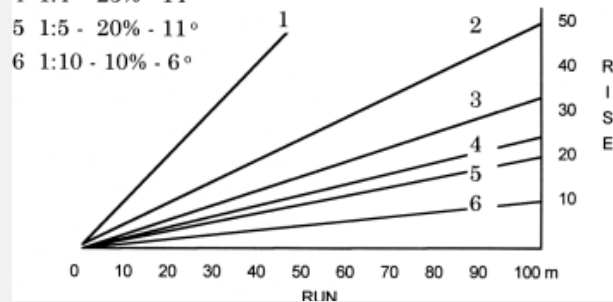


- ▶ Slopes describe “steepness” of a feature
 - ▶ Listed as a percentage or a ratio
 - ▶ Ratio = X horizontal distance : Y vertical distance (Rise/Run)
 - ▶ Percentage = (vertical distance / horizontal distance) X 100
 - ▶ Example: 10% slope = 10:1 slope

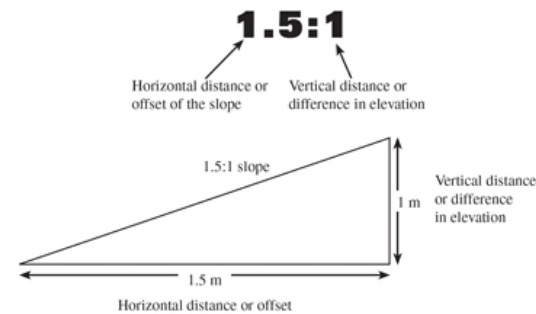


Slope Gradients

- 1 1:1 - 100% - 45°
- 2 1:2 - 50% - 27°
- 3 1:3 - 33% - 18°
- 4 1:4 - 25% - 14°
- 5 1:5 - 20% - 11°
- 6 1:10 - 10% - 6°



Slope ratios compare the horizontal distance to the vertical distance.



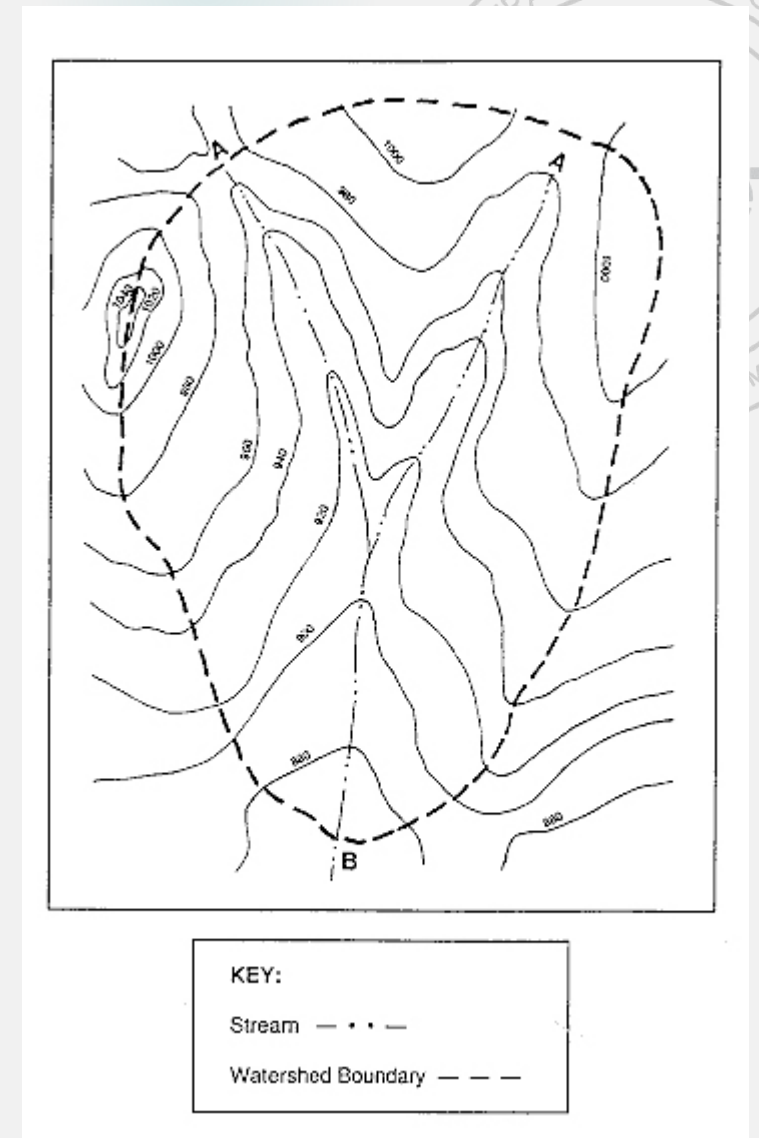
Note: The vertical distance is the difference in elevation and is sometimes called the rise or fall.

OVERVIEW

Site Management Basics

Watershed Map

- ▶ A watershed map typically lists the ridge and valley (or stream) lines based upon contours.
 - ▶ In the diagram, the points listed as "A" are where streams start to flow and "B" is the "collection point" or the "area of concentration for flow".

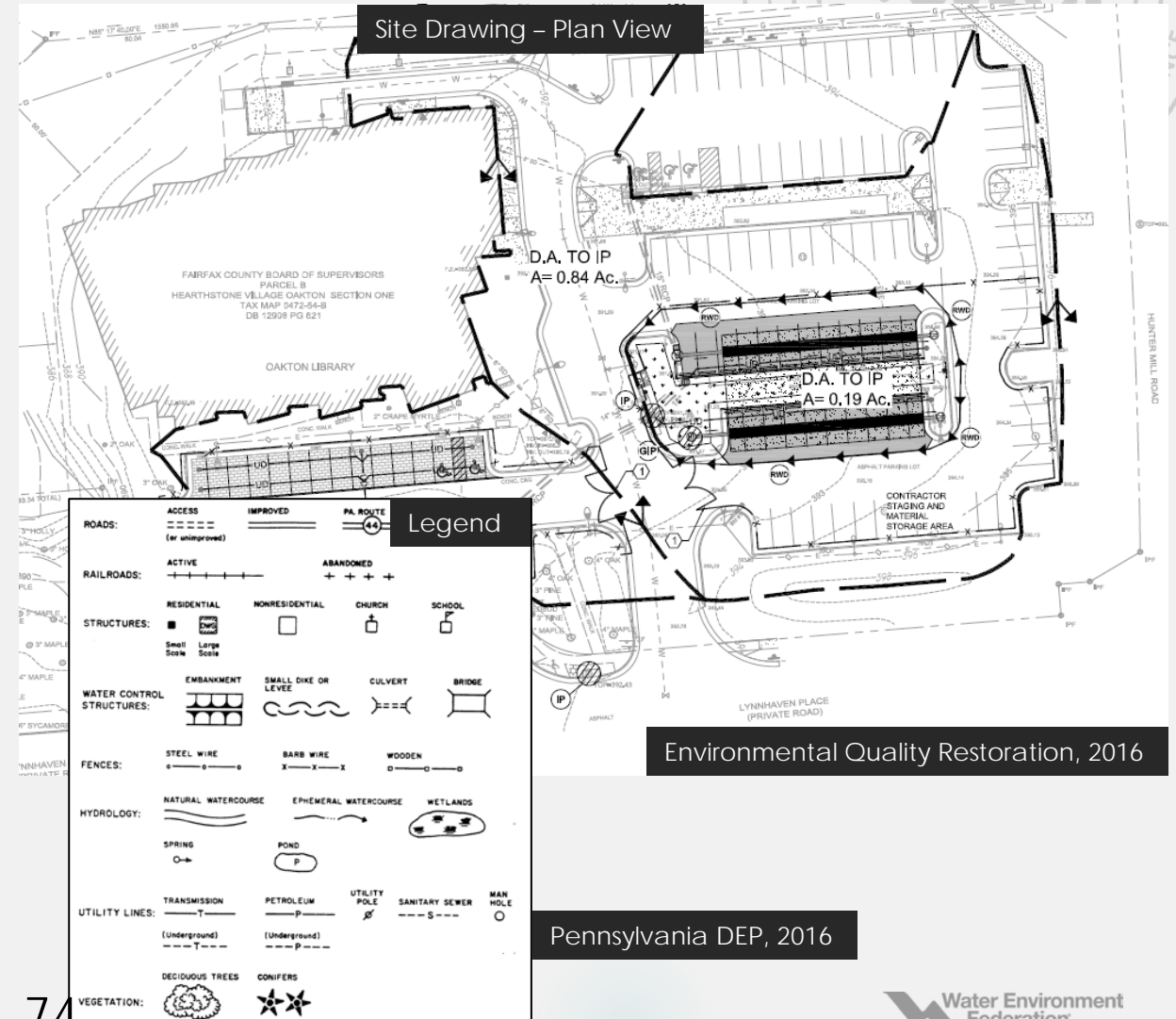


Watershed Map, USGS, 2017

OVERVIEW

Site Management Basics - Construction Documents

- ▶ Stormwater site plans typically consist of:
 - ▶ Title page – provides project name, location and designer information
 - ▶ Site drawings – a “plan” view (looking down on a site) that is usually broken into multiple drawings and shown at a specific scale (e.g., 1" = 20 ft)
 - ▶ Legend: what symbols mean
 - ▶ Topography (“topo”) lines: “shape of the landscape”
 - ▶ Site locations of existing features (light lines) versus proposed features (darker lines) – topo (site grading), GI practices, utilities, vegetation, and property lines
 - ▶ Details for building proposed practices
 - ▶ Erosion and sediment control practices to reduce the amount of sediment carried off-site during construction

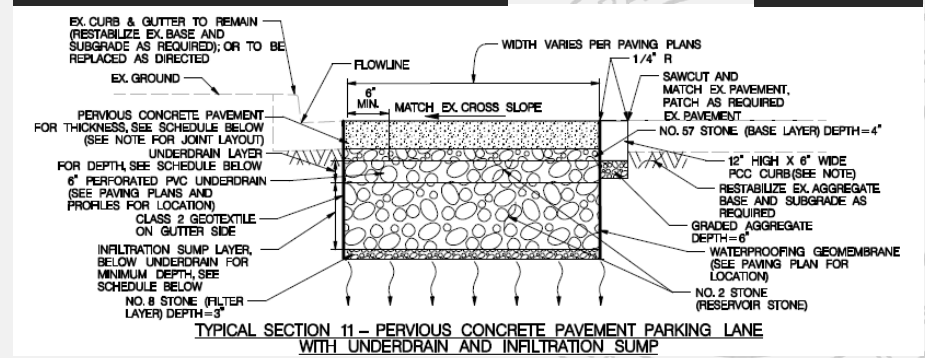


OVERVIEW

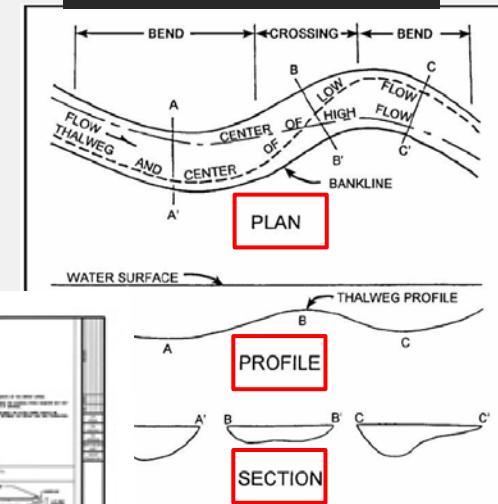
Site Management Basics - Construction Documents

- ▶ Stormwater site plans typically consist of:
 - ▶ Cross-section ("section") – a view of critical elements as seen if you cut "across" a stream or stormwater practice
 - ▶ Longitudinal profile – a view of critical elements as seen if you cut a stream or stormwater practice "in half"
 - ▶ Standard details – a close-up view of critical elements (stormwater practice, pipe outfall, etc.) to clarify how to construct the element
 - ▶ Narrative – a description of the project, such as phasing, seasonal issues, critical/sensitive areas, etc.

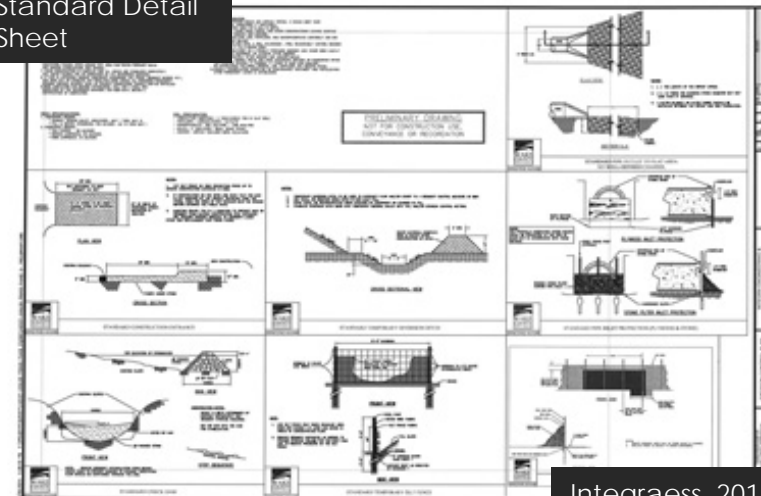
Typical Detail (Pervious Concrete)



Plan-Profile-Section Views



Standard Detail Sheet



Integraess, 2016

StudyBlue, 2016

OVERVIEW

Site Management Basics - Common Equipment



- ▶ Commonly used construction equipment on stormwater projects – smaller (compact) equipment
- ▶ Minimizes compaction impacts and impacts to environmentally sensitive areas/resources

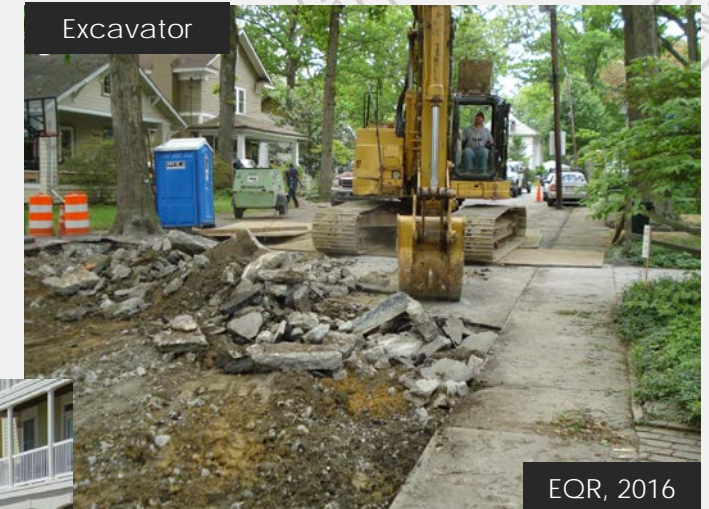


OVERVIEW

Site Management Basics - Common Equipment



- ▶ Commonly used construction equipment on stormwater projects – heavy equipment
 - ▶ Size of equipment determined by reach, activity type and access



OVERVIEW

Site Management Goals (During Construction)



- ▶ Preserve and maintain existing vegetation as much as possible through project phasing and construction sequencing.
- ▶ Protect existing trees, utilities, structures, etc. from sediment and/or erosion damage.



OVERVIEW

Site Management Goals (During Construction)



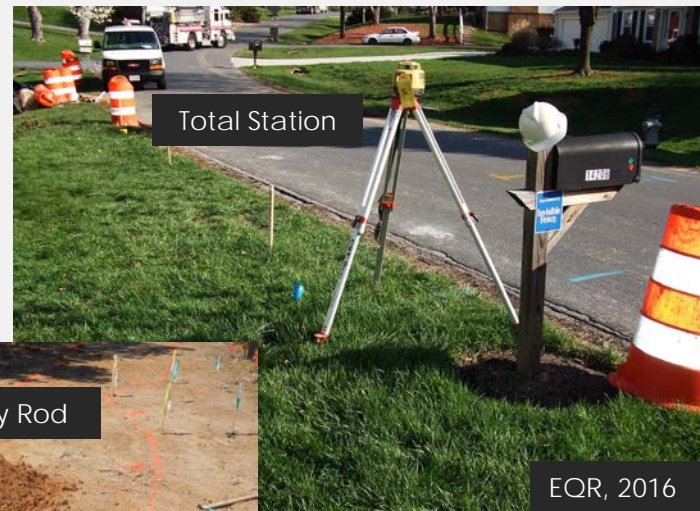
- ▶ Protect site from offsite stormwater flows – divert around construction limits.
- ▶ Prevent construction site activities from adding pollutants to stormwater flow.
- ▶ Prevent construction site activities from increasing stormwater flow rates.



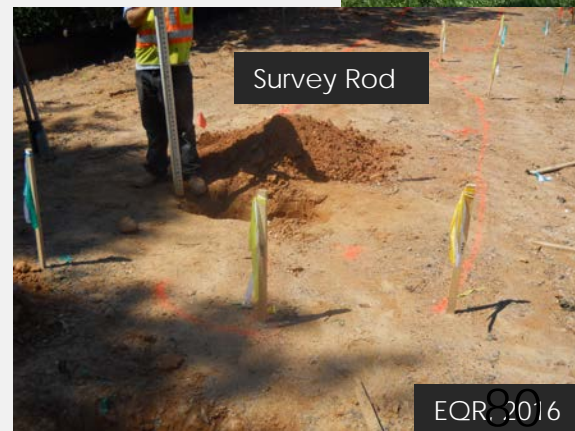
OVERVIEW

Site Management Goals (During Construction)

- ▶ Identify and protect survey markings and stakeout information.
- ▶ Equipment:
 - ▶ "Total Station"
 - ▶ "Survey Rod"
 - ▶ "Stakes"



EQR, 2016

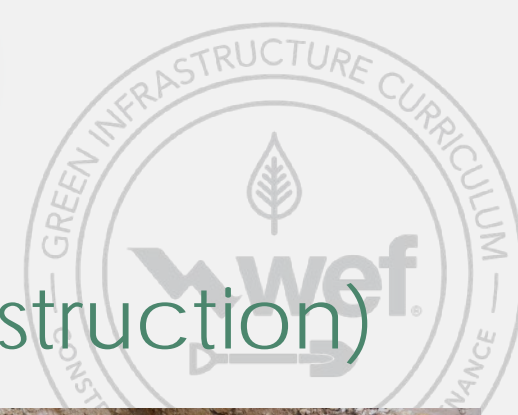


White	PROPOSED EXCAVATION
Fluorescent Pink	TEMPORARY SURVEY MARKINGS
Red	ELECTRIC POWER LINES, CABLES, CONDUIT AND LIGHTING CABLES
Yellow	GAS, OIL, STEAM, PETROLEUM OR GASEOUS MATERIALS
Orange	COMMUNICATION, ALARM OR SIGNAL LINES, CABLES OR CONDUIT
Blue	POTABLE WATER
Purple	RECLAIMED WATER, IRRIGATION AND SLURRY LINES
Green	SEWERS AND DRAIN LINES



OVERVIEW

Site Management Goals (During Construction)



- ▶ Identifying and locating utilities in the field is a challenge.
 - ▶ Anticipate the chance of encountering utilities, especially in heavily urbanized areas.



OVERVIEW

Site Management Goals (During Construction)



- ▶ Identify and mark areas of high seasonal groundwater table.
 - ▶ Encountering groundwater unexpectedly will likely change GI practices and features.



Photo of Unanticipated Ground Water Table, EOR, 2017

OVERVIEW

Site Management Goals (During Construction)



- ▶ Manage site to protect construction materials prior to installation.
 - ▶ Example: prevent topsoil from washing into downstream stone pile.
- ▶ Protect new practices from sediment and/or erosion damage, etc. prior to full site stabilization.
- ▶ Coordinate with subcontractors to protect new practices from sediment damage.



OVERVIEW

Site Management Goals (During Operation)



- ▶ Stockpile maintenance materials to avoid damage to the practice.
 - ▶ Example: Stockpile in a location to avoid washing fine material into downstream areas that can be damaged.



OVERVIEW

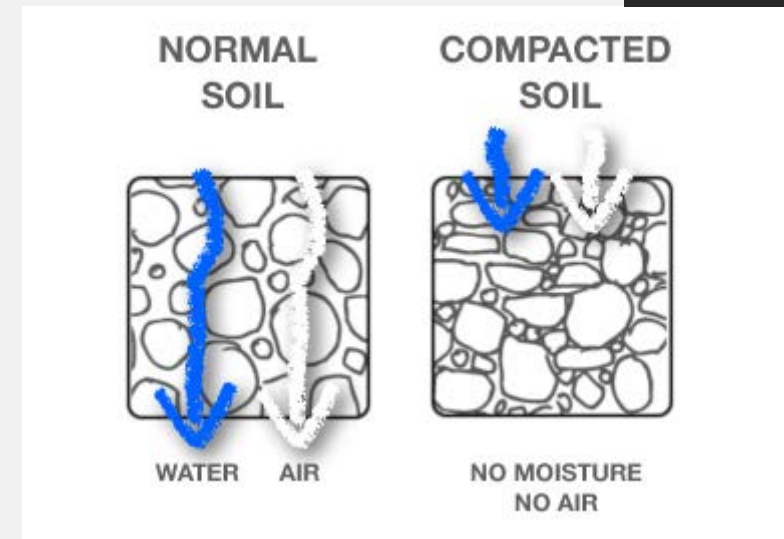
Site Management Goals (During Operation)



EQR, 2016

► Compaction Issues

- Significant due to tie with infiltration
- High compaction = lower infiltration capacity
- High infiltration rates important for GI practice functioning
- Must ALWAYS be concerned with over-compaction of soils and materials
 - Over-compaction: compaction of soils/materials to the point where they do not function as intended



Compacted Soil Reduces Moisture and Air Penetration and Holding Capacity

OVERVIEW

Site Management Goals (During Operation)

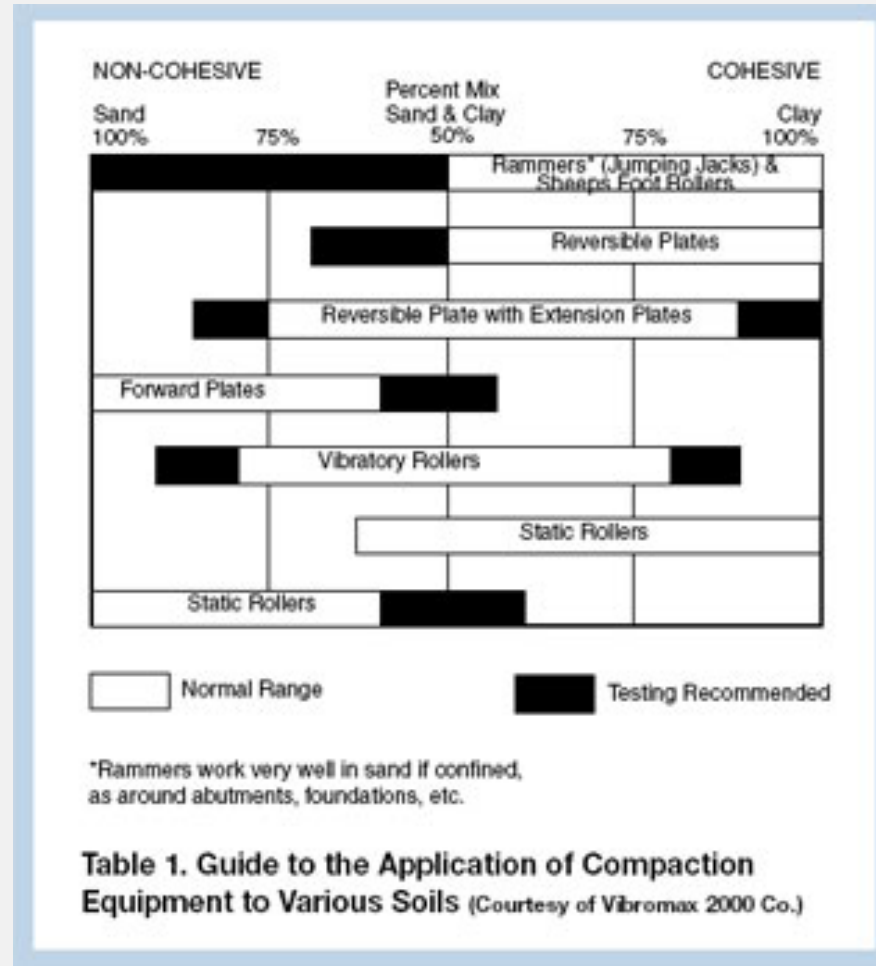


► Compaction Equipment

- Varies by soil type
- Compaction increased by weight of equipment and amount of vibration

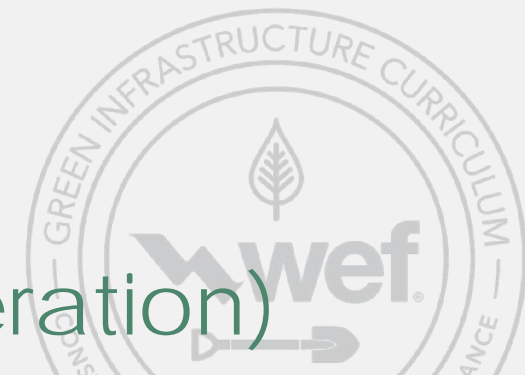
► Compaction Equipment Types

- Rammers / Jumping Jacks
- Reversible Plates
- Forward Plates
- Vibratory Rollers
- Static Rollers



OVERVIEW

Site Management Goals (During Operation)



- ▶ **Compaction Equipment**

- ▶ Rammers / Jumping Jacks
- ▶ Forward Plates
- ▶ Reversible Plates
- ▶ Vibratory Rollers
- ▶ Static Rollers

Engineering Intro, 2016



Vibratory Roller

Altrad, 2016



Forward Compaction Plates

Altrad, 2016



Reversible Compaction Plates

Nickell Rental, 2016



Rammer / Jumping Jack



EQR, 2016



Sheep Foot / Tamping Static Roller

OVERVIEW

Site Management Goals (During Operation)



- ▶ Develop ongoing landscape and maintenance guidelines to prevent damage to the practice.
- ▶ Examples:
 - ▶ Avoid mulch delivery and stockpiling on permeable pavement.
 - ▶ Do not apply pesticides or herbicides in bioretention cells or green roofs.



SITE MANAGEMENT DURING CONSTRUCTION

Definitions



- ▶ Erosion: the wearing away of the land surface by running water, wind, ice, or gravity, or the detachment and movement of soil or rock fragments by water, wind, ice, or gravity.



SITE MANAGEMENT DURING CONSTRUCTION

Definitions



- ▶ Sediment: fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits, and is transported by, suspended in, or deposited by water.

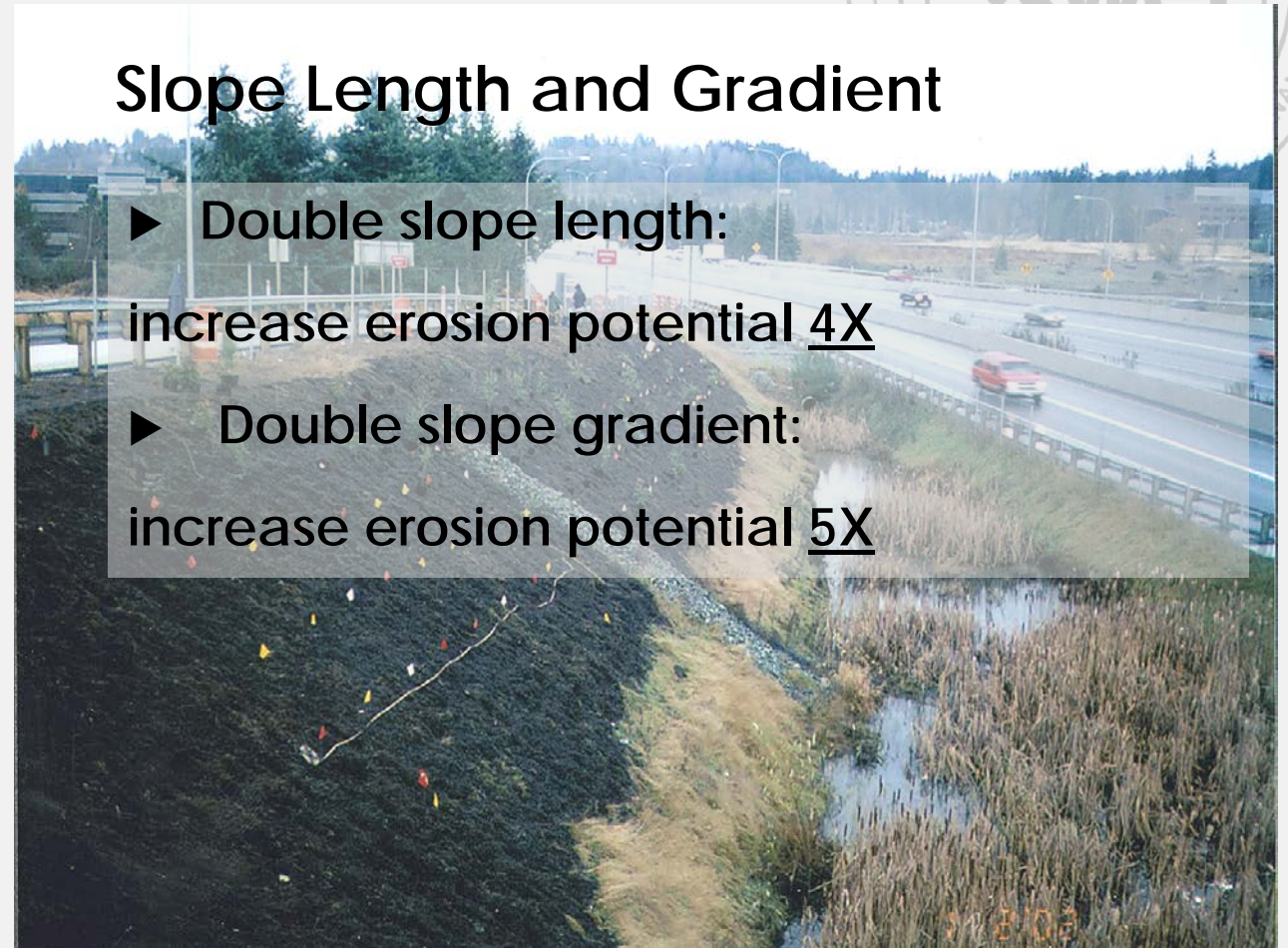


SITE MANAGEMENT DURING CONSTRUCTION

Source of Pollutants

Characteristics that make sites more susceptible to erosion:

- ▶ Steep slopes
- ▶ Loose (uncompacted) soils
- ▶ Lack of stabilizing ground/surface cover (e.g., vegetation, mulch, gravel, pavement, structure, etc.)
- ▶ Run-on from off-site areas



Most sediment control BMPs function by shortening slope

SITE MANAGEMENT DURING CONSTRUCTION

Methods to Control Pollutants (Types of ESC)



Silt Fence



Wattles



Vegetation





MODULE 6

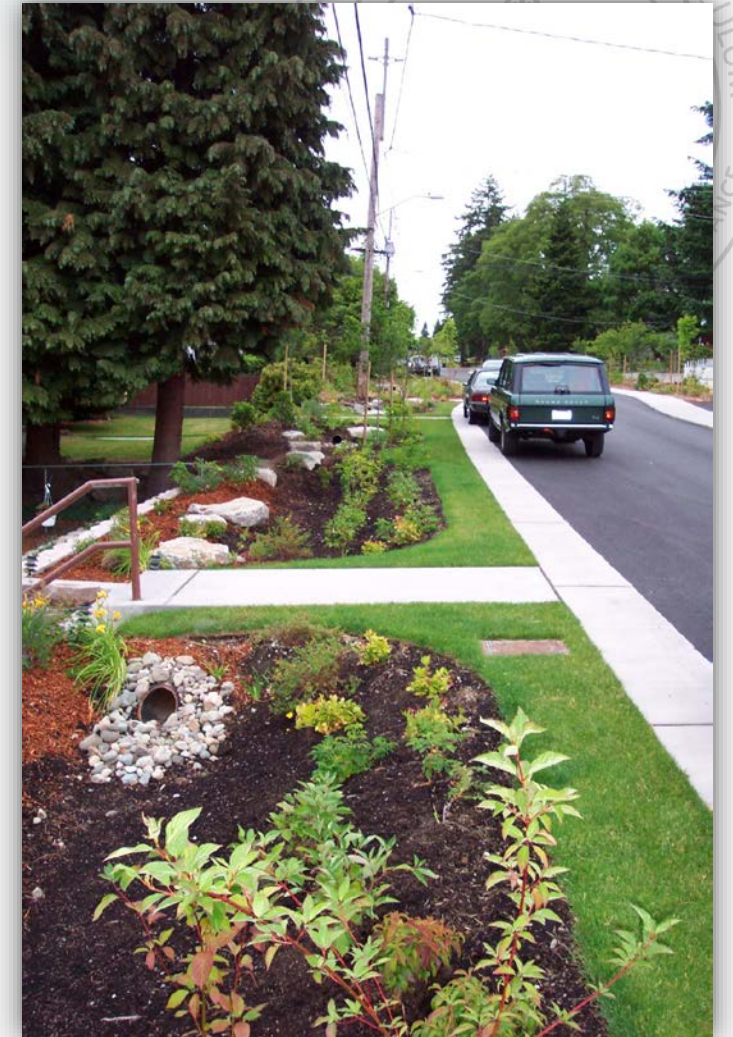
Bioretention Practices



COMPONENTS & PROCESSES

What is bioretention?

- ▶ Small-scale, vegetated depressions that receive stormwater from small contributing areas (e.g., a section of road and rooftops), and are used to slow, store and treat stormwater runoff
- ▶ Treats stormwater runoff by infiltration/percolation through soil and plant roots and physical, chemical, biological processes
 - ▶ Slowed, cleaned water allowed to infiltrate through native soils or directed to nearby stormwater drains or receiving waters
- ▶ May be single cells or cells that are connected for flow control, water quality treatment and conveyance



City of Seattle, WA

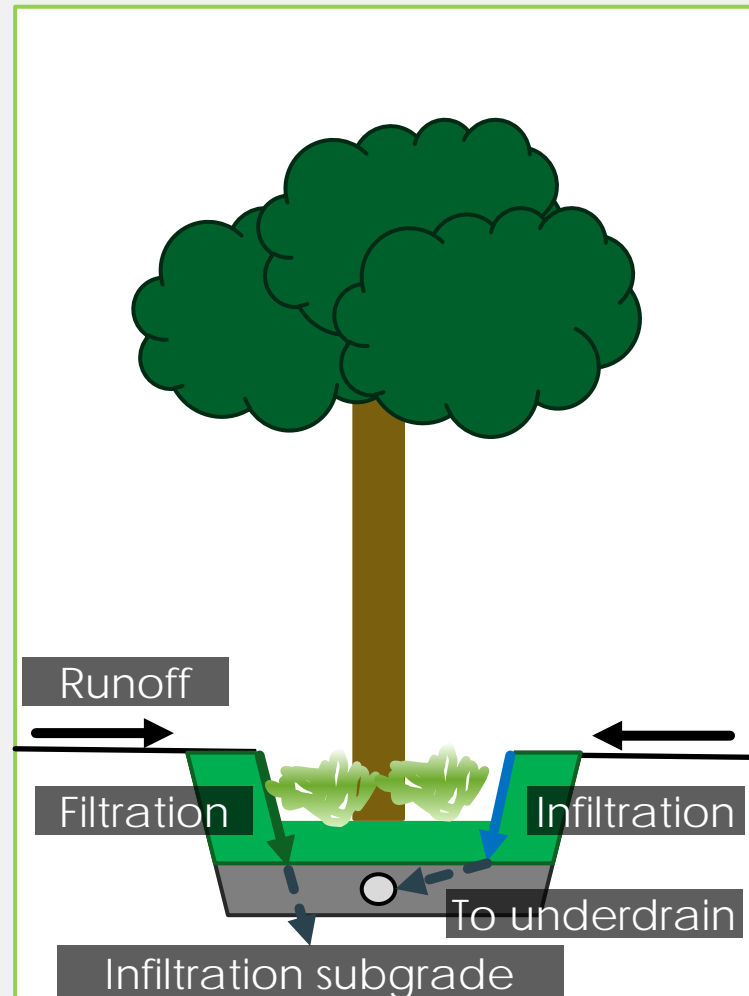
COMPONENTS & PROCESSES

Bioretention Facilities



How does it work?

- ▶ Water enters and moves vertically through planted, engineered soil media
- ▶ Infiltrates into subgrade flows to underdrain
- ▶ Overflows through a controlled outlet during large storms



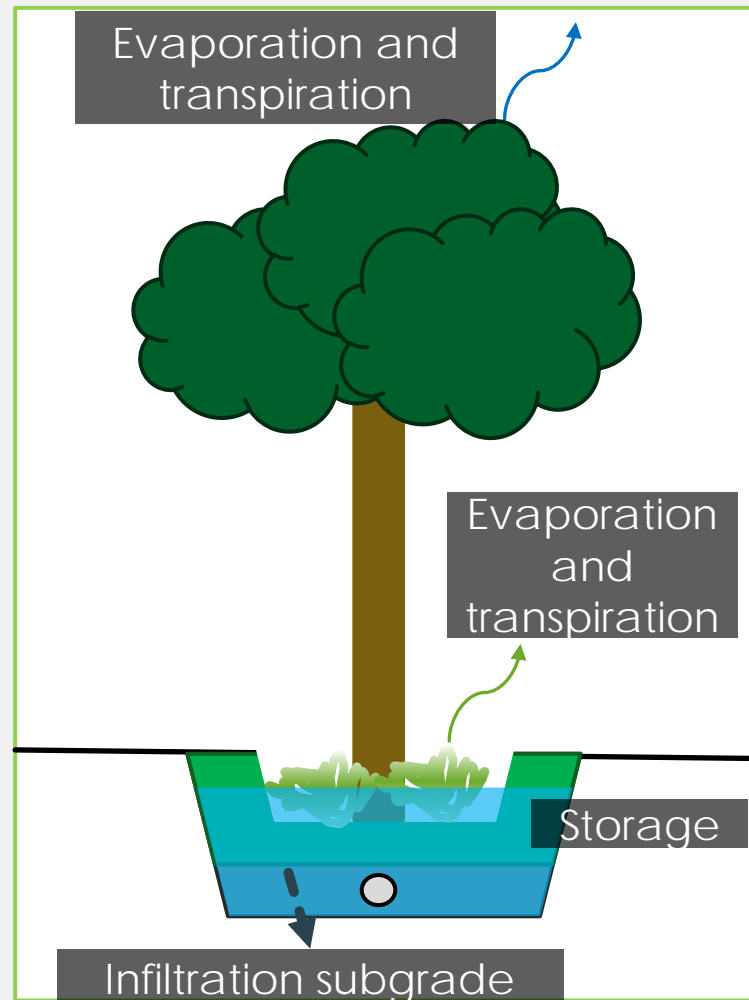
COMPONENTS & PROCESSES

Bioretention Facilities



How does it work?

- ▶ Can provide stormwater flow and volume reduction.
- ▶ Plants and media physically filter and chemically bind stormwater contaminants.



TYPES OF BIORETENTION



Bioretention Cells

- ▶ Single-family lots
- ▶ Commercial areas
- ▶ Parking lots



Rain Gardens

- ▶ Single-family lots
- ▶ Small commercial areas



Planters & Planter Boxes

- ▶ Highly urban areas
- ▶ Right-of-way and adjacent to buildings



Bioretention Swales/ Bioswales/Vegetated Swales

- ▶ Typically in right-of-way



Vegetated Curb Extensions

- ▶ Bioretention incorporated into right-of-way in urban and suburban areas

TYPES

Bioretention Cells

What are bioretention cells?

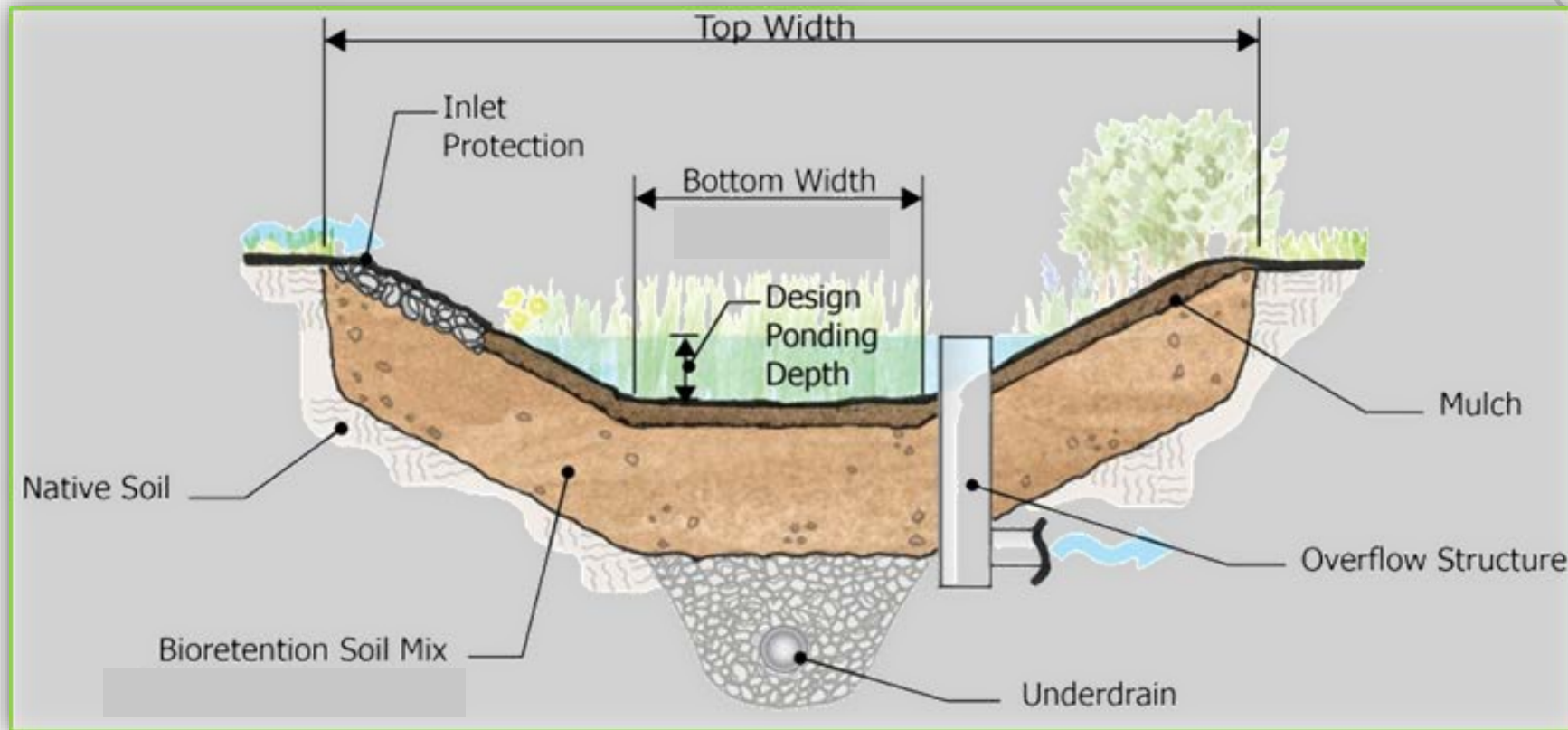
- ▶ Shallow vegetated depressions
- ▶ Gentle side slopes typical
- ▶ Can be designed as individual stormwater receiving areas or linked to conveyance system
- ▶ Designed soil media
- ▶ Optional underdrains/control structures



City of Portland, OR



BIORETENTION CELL Standard Detail



City of Seattle, WA

TYPES

Rain Gardens



What are rain gardens?

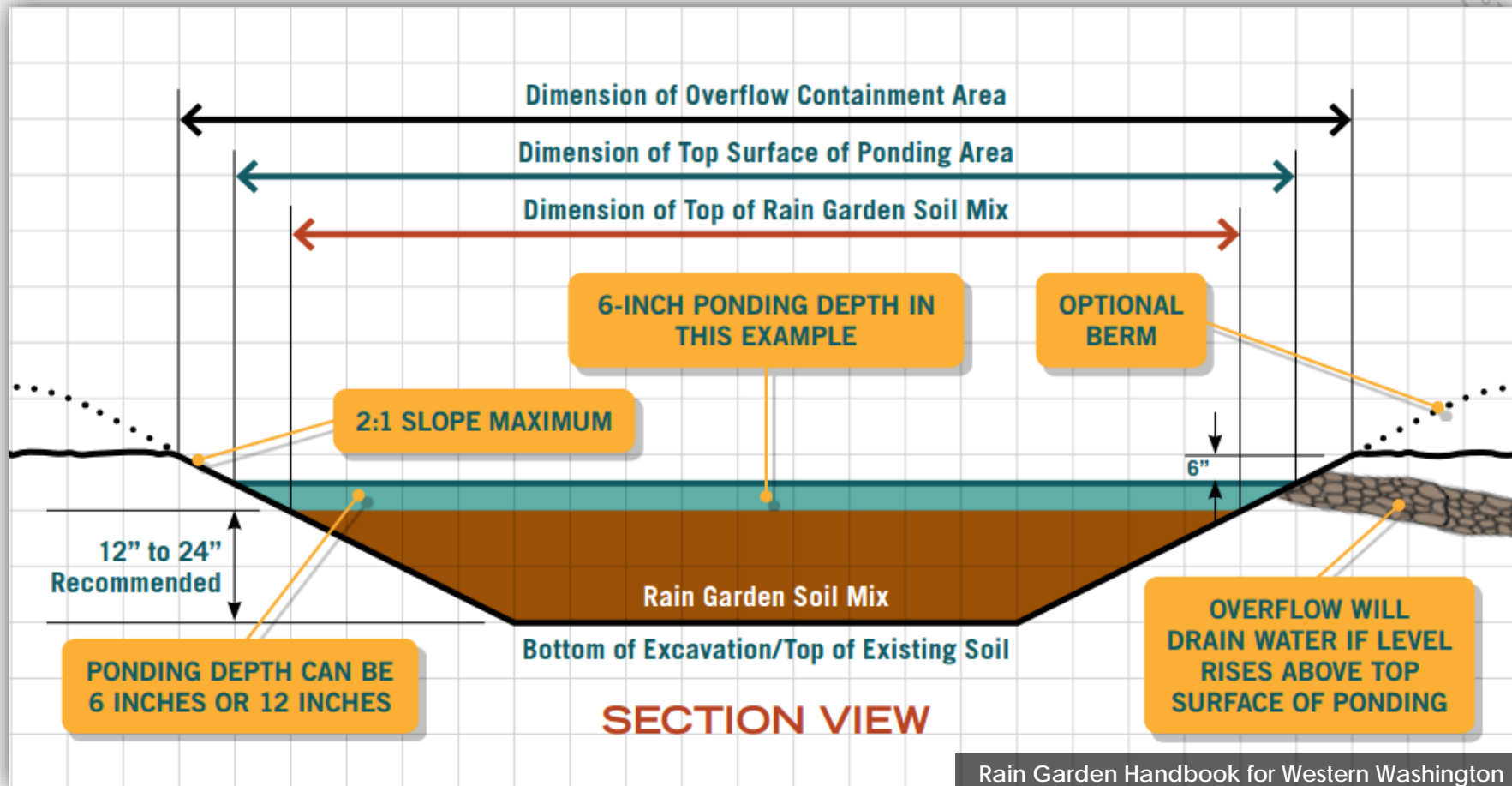
- ▶ Same as bioretention cell, except:
 - ▶ Soil may or may not be amended
 - ▶ Usually no underdrains/control structures
 - ▶ Specific subgrade soil properties less restrictive than bioretention
 - ▶ Typically receives less water quality treatment and flow control credit than bioretention



City of Puyallup, WA

RAIN GARDENS

Cross-Section



TYPES

Bioretention Swales



What are bioretention swales/bioswales/vegetated swales?

- ▶ Same design features as bioretention cells
- ▶ Interconnected series of bioretention cells
- ▶ Conveys stormwater (i.e., water typically flows in and excess water flows out to the street or to a connected swale or other stormwater control)

Note that bioretention cells provide treatment by infiltrating stormwater vertically through soil, but bioswales provide treatment by water moving horizontally along the surface and through surface vegetation.



City of Seattle, WA

BIORETENTION SWALE

Typical Application

What is a typical bioretention swale application?

- ▶ Bioretention swales are often located along roads and are typically long linear facilities.



City of Seattle, WA



TYPES

Vegetated Curb Extensions



What are vegetated curb extensions?

- ▶ Also known as “bulb-outs” or “bump-outs”
- ▶ Bioretention located along a road and within an area where the curb line has been extended into the road
- ▶ Water enters through curb cuts
- ▶ Designed soil media
- ▶ Often used in residential settings for traffic calming



Portland, OR

TYPES

Bioretention Planters



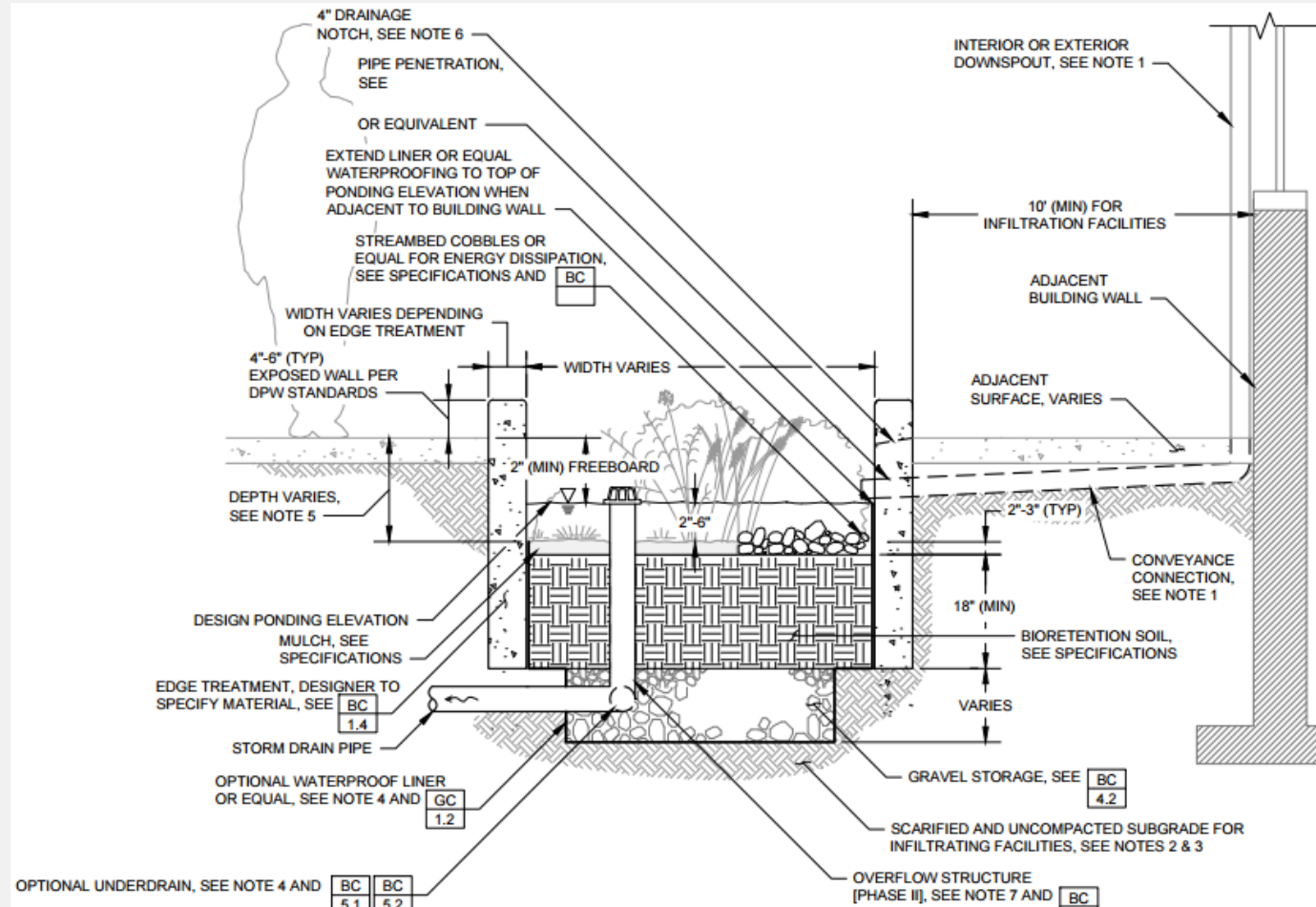
What are bioretention planters?

- ▶ Also, known as “bioretention planter boxes” or “stormwater planter boxes”
- ▶ Vertical walled reservoir (typically concrete)
- ▶ Designed soil media
- ▶ Often used in ultra-urban settings
- ▶ May have an open bottom to allow infiltration to native soil or be lined with an underdrain to protect adjacent buildings or other infrastructure



Portland, OR

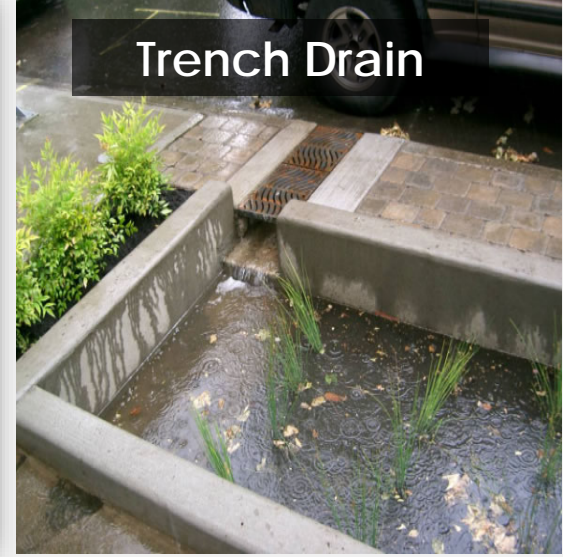
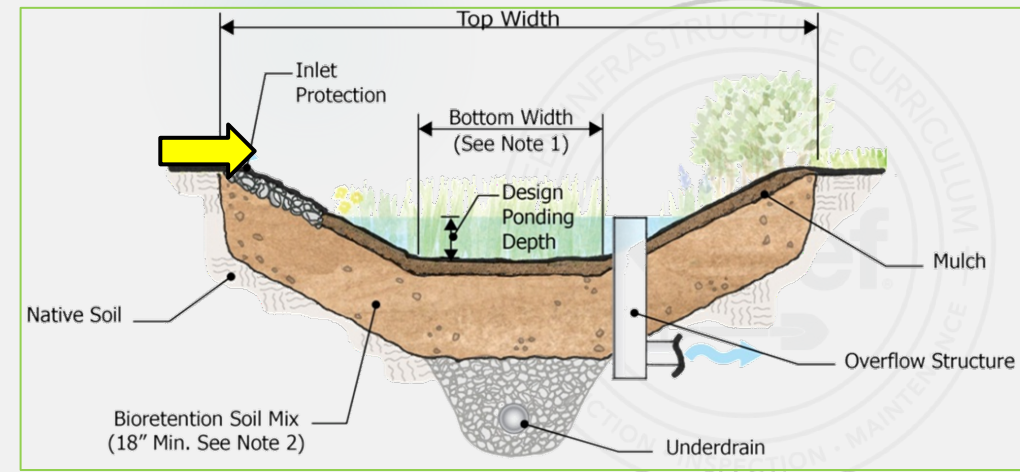
BIORETENTION PLANTER Cross-Section



City of San Francisco Standard Details

INLET

Types of Inlets

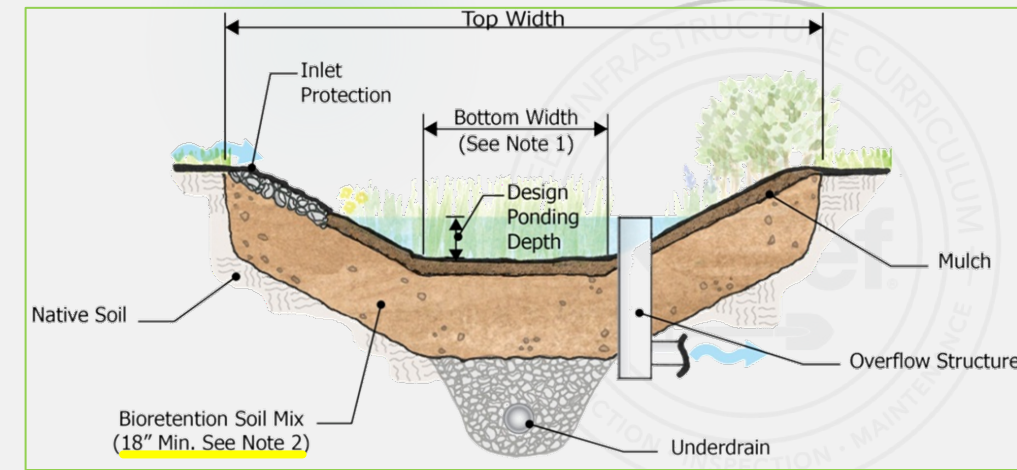


COMPONENTS

Bioretention Soil Mix

- ▶ Allows water to soak in rapidly
- ▶ Treats runoff
- ▶ Supports healthy plant growth

Note that specific bioretention soil mix components will vary regionally, but material should always be free of weed seeds and contaminants.



COMPONENTS

Underdrains (Optional)

Without Liner

- ▶ Some infiltration to native soil

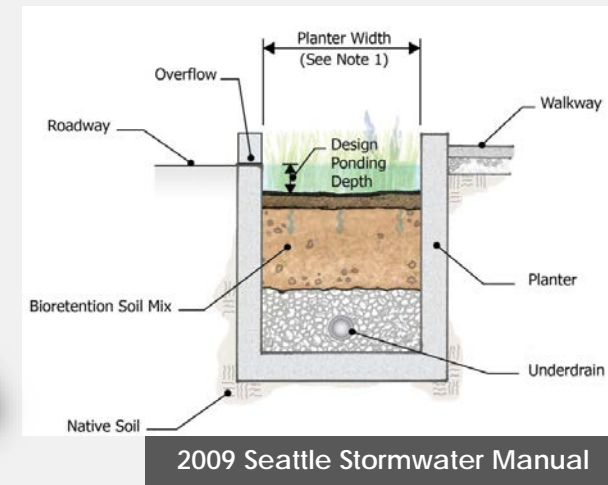
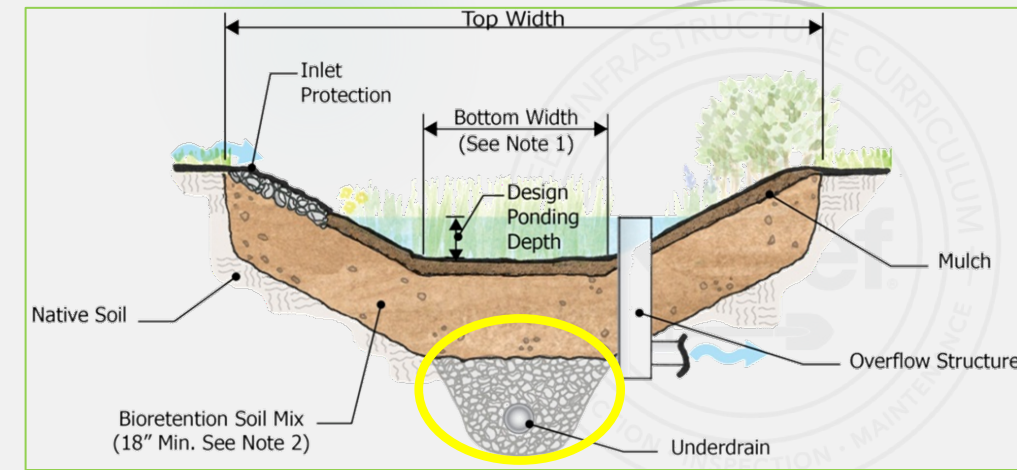
With Liner

- ▶ Liner types: clay (bentonite), geomembrane, planter
- ▶ No infiltration to native soil to prevent leakage to underlying or adjacent structures

Underdrain Pipe Bedding/Filter Layer

- ▶ Sandy-gravel material
- ▶ 6" min below underdrain*
- ▶ 12" min above and on sides of underdrain*
- ▶ A storage layer may be incorporated below underdrain

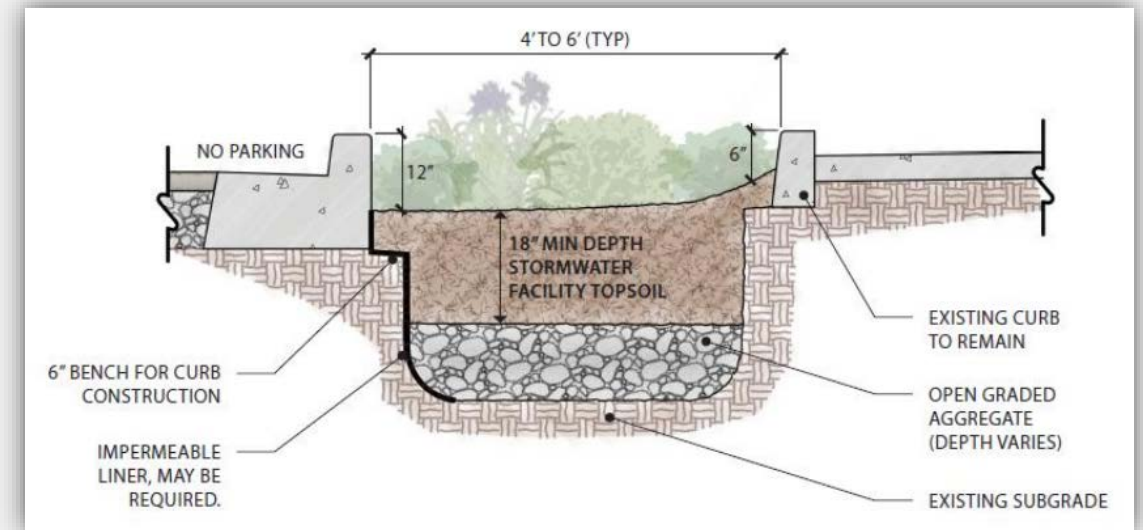
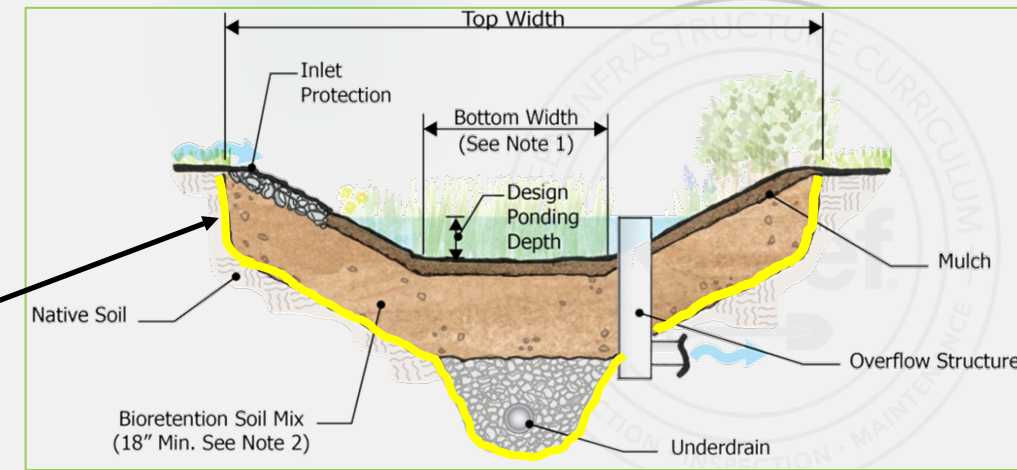
*Specific distances are normally provided by local codes/standards.



COMPONENTS

Geotextile (Optional)

- ▶ Not recommended between existing soil and media because of potential to clog.
- ▶ If a storage reservoir with large rock is installed at the bottom of a bioretention practice, use an intermediate layer of stone between the soil media and the coarser rock to prevent migration of finer material rather than geotextile.
- ▶ May be installed on sides of bioretention practice to protect adjacent infrastructure or below check dams or inlet stone to prevent weed establishment and erosion.



COMPONENTS

Plants

Plants provide multiple benefits in bioretention areas, including:

- ▶ Improved water flow through the soil by root penetration.
- ▶ Promotion of healthy soil organisms.
- ▶ Improved soil structure.
- ▶ Evaporation of precipitation and transpiration of soil water.
- ▶ Creation of habitat for insects and birds.
- ▶ Creation of more pleasing aesthetics.



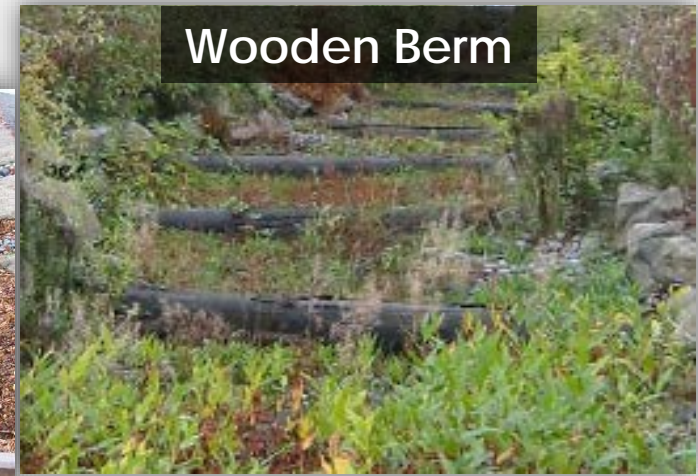
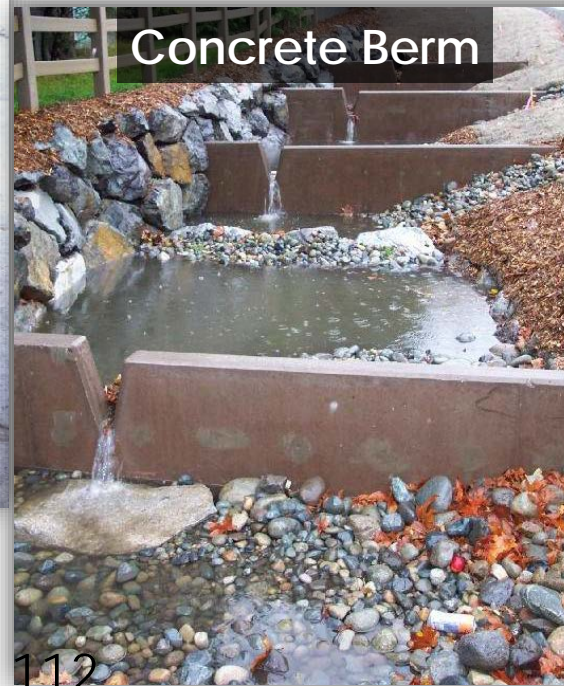
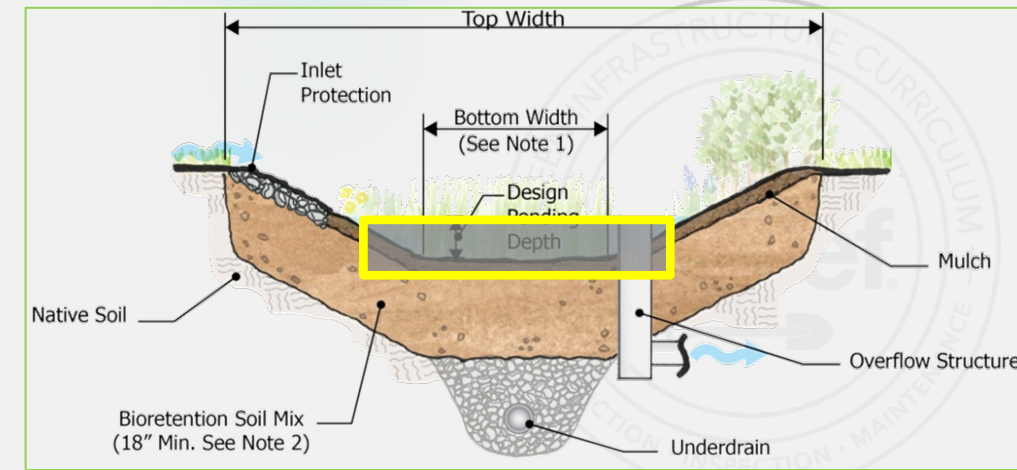
City of Seattle, WA



COMPONENTS

Berms/Check Dams

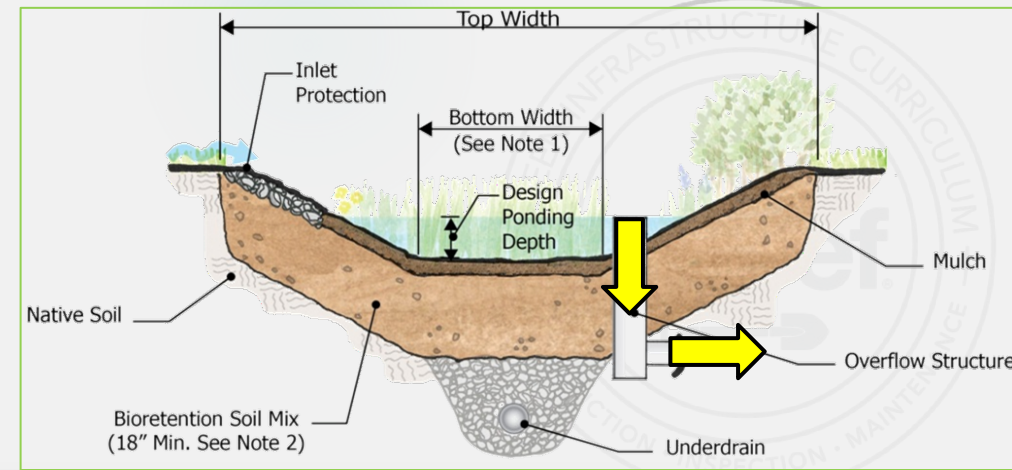
Berms/check dams control (slow) the flow of water through bioretention on slopes.



COMPONENTS Overflow

Types of overflow:

- ▶ A low spot in the earthen rim around the bioretention area (must be protected from erosion)
- ▶ Catch basin
- ▶ Vertical stand pipe
- ▶ Horizontal pipe
- ▶ Curb-cut overflow
- ▶ Can be connected to underdrain system





MODULE 7

Permeable Pavement



GENERAL OVERVIEW

Permeable/Porous Pavements



- ▶ Permeable pavements:
 - ▶ Are similar to conventional pavement as they provide structural support for vehicle, bicycle, and pedestrian traffic.
 - ▶ Have the additional benefit of allowing water to infiltrate through the pavement surface, aggregate base, and if desired, to the subgrade soils.
 - ▶ Receive stormwater runoff generated by nearby buildings and non-permeable paved areas.
- ▶ Surrounding areas and surfaces should be stabilized before runoff should be accepted into permeable pavement areas.



GENERAL OVERVIEW

Permeable/Porous Pavements



▶ **Traditional pavements** are designed to support a variety of different sizes and weights of vehicles under a range of speeds and weather conditions. They are impervious – they do not allow water to pass through.

▶ **Permeable pavements** are designed to also support many of the same vehicular loads but to also allow water to pass through the pavement surface and to be temporarily stored in the aggregate base until infiltration occurs.



GENERAL OVERVIEW

Permeable/Porous Pavements



- ▶ **Aggregate base** is the rock placed under the permeable pavement. This can range from a few inches to two or three feet to meet structural and water storage requirements.



TYPES OF PERMEABLE PAVEMENT



There are four classes/types of permeable pavement:

Porous Asphalt



Pervious Concrete



Permeable Pavers

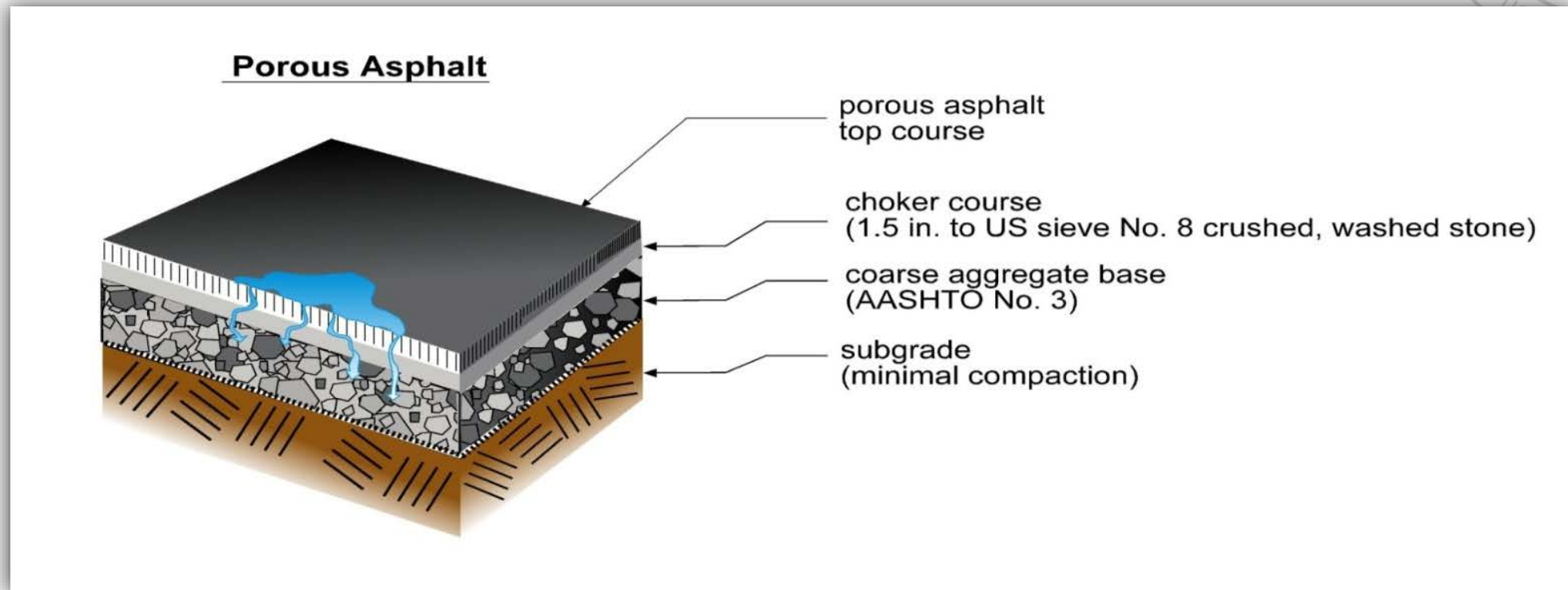


Plastic Grid Systems



TYPES OF PERMEABLE PAVEMENT

Porous Asphalt Components



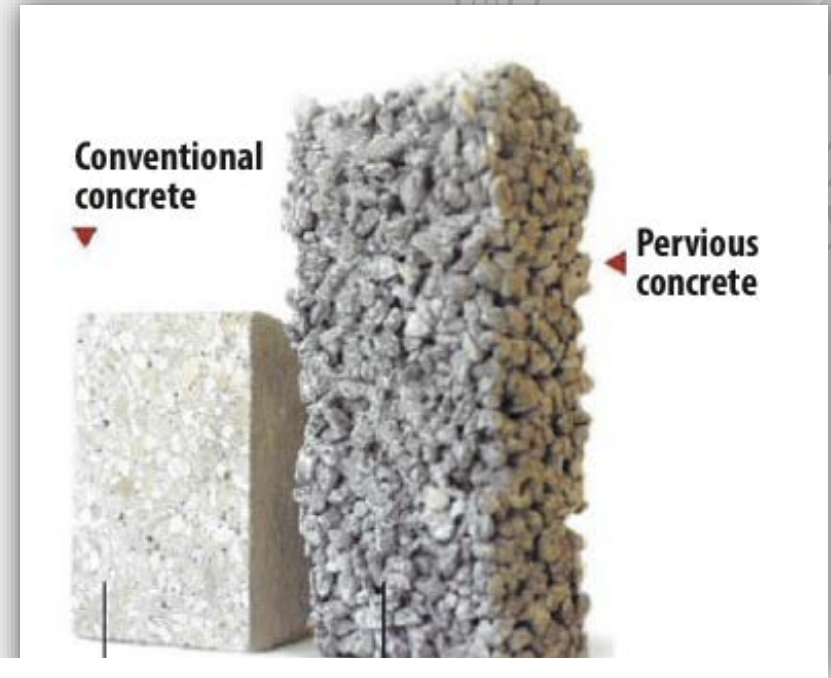
Example porous asphalt section

TYPES OF PERMEABLE PAVEMENT

Pervious Concrete

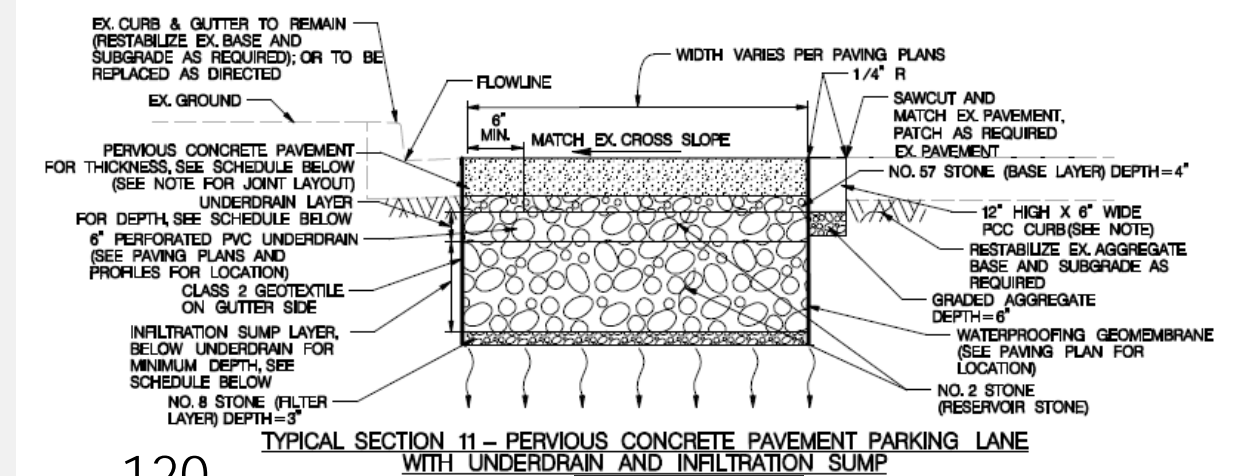


- ▶ Pervious concrete can handle heavy vehicle loads, but is typically used for parking and slower speed applications.



Non-Pervious Concrete

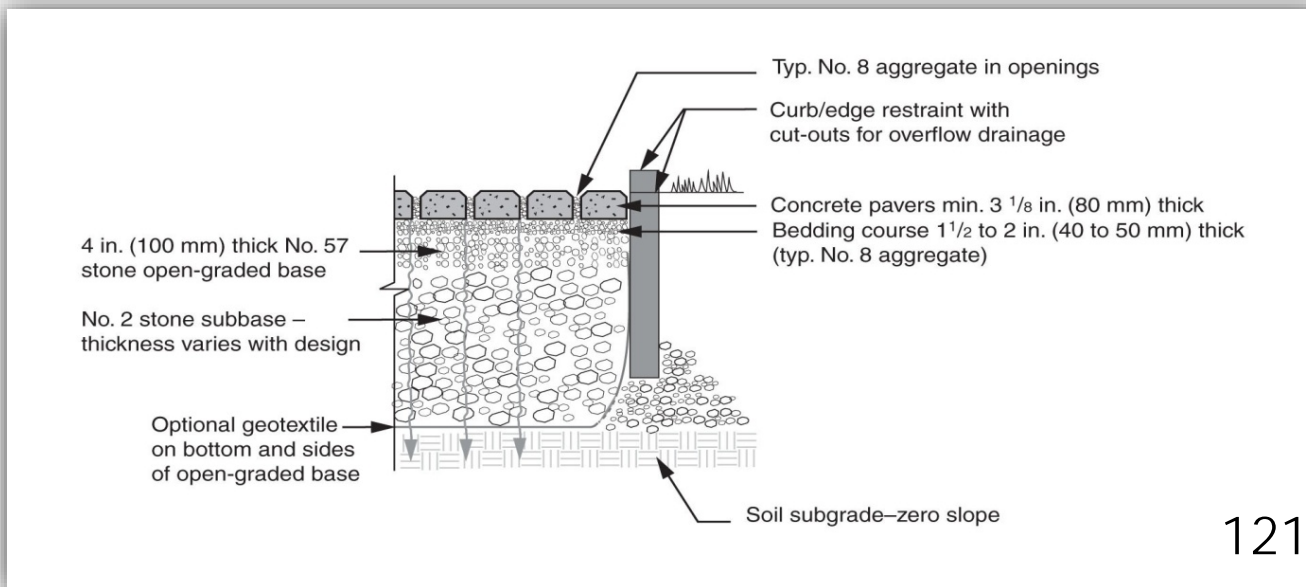
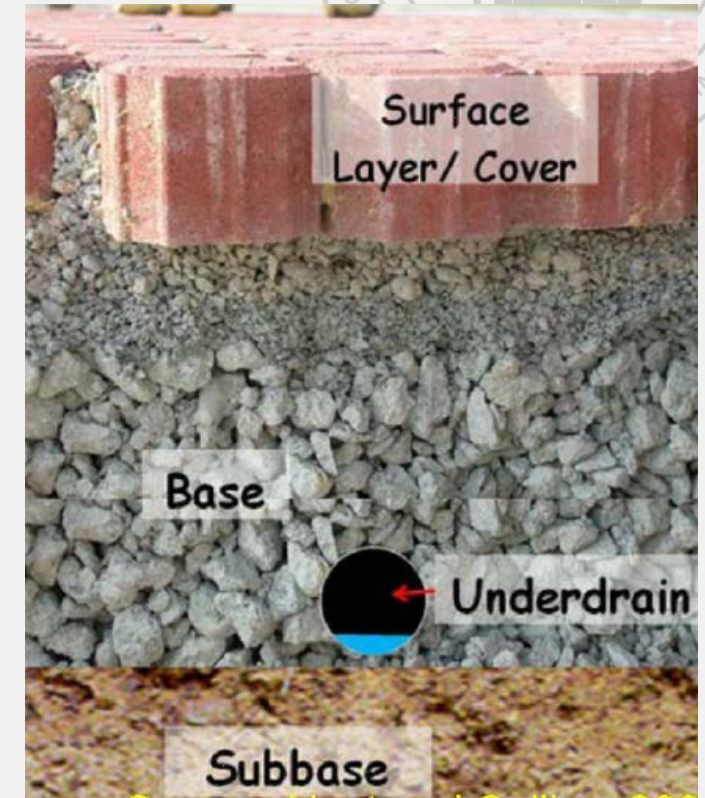
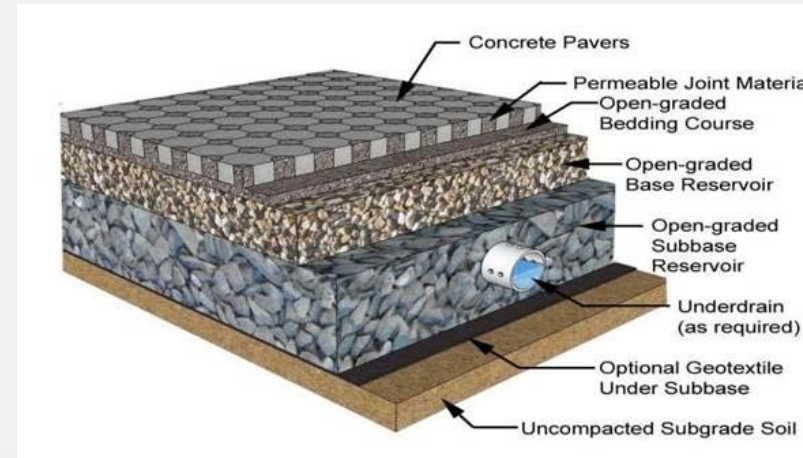
Pervious Concrete



Pervious and Non-Pervious Concrete in Fresno, CA (Concrete Décor, 2016)

TYPES OF PERMEABLE PAVEMENT

Permeable Paver System Construction Sequence



TYPES OF PERMEABLE PAVEMENT

Plastic Grid Systems



- ▶ Plastic grid systems are plastic cellular paving grids for reinforcing grass, gravel, or stones to create a surface that is safe and easy to walk, ride, and drive on, while allowing water to infiltrate.
- ▶ Plastic grids are capable of carrying heavy vehicular loads, but used for slower speed applications (e.g., parking lots) or areas where grass and other similar vegetation is expected to grow.



CONSTRUCTION SEQUENCE

Permeable Pavement Systems



Excavation performed from outside the footprint of the permeable pavement area



Tillage and ripping done to scarify native soil



Compaction of aggregate base layer often done using vibratory roller and compaction done every 6-inch lift

INSPECTION AND MAINTENANCE

Working Properly – Permeability



Working Properly

Stormwater is infiltrating during storms and there is no ponding water soon after precipitation stops.

There is not excessive sediment or plant growth clogging pavement pores.



Not Working Properly

Water is ponding for extended periods (determined from local conditions, but often longer than 1 hour is a sign of excessive clogging).

Excessive sediment build-up and/or plant growth on pavement surface prohibiting infiltration.

INSPECTION AND MAINTENANCE Working Properly – Structural



Working Properly

There is not excessive (at most, small, isolated patches) raveling (aggregate coming loose on pavement surface).

Not Working Properly

There is excessive raveling (aggregate coming loose on pavement surface).

Concrete or asphalt is cracking or pavers are settling unevenly indicating unstable subgrade, improper aggregate base installation or excessive point loads.



INSPECTION AND MAINTENANCE

Typical Maintenance Tasks



- ▶ Clean pavement with high efficiency vacuum, sweeper-vacuum, or walk behind vacuum to remove surface debris.



INSPECTION AND MAINTENANCE

Typical Maintenance Tasks



- ▶ Identify and stabilize any sediment sources to pavement area.
- ▶ Maintain adjacent landscaping to prevent excessive growth and debris onto pavement.



INSPECTION AND MAINTENANCE

Typical Maintenance Tasks

- ▶ Remove excessive moss or other plant growth from pavement using pressure wash, weed burners, or regular street sweeping equipment.



INSPECTION AND MAINTENANCE

Typical Maintenance Tasks



- ▶ Snow removal
 - ▶ Salt application can often be reduced significantly for permeable pavement since water drains and black ice does not easily form. Also, salt applications stay on the permeable pavement longer since it does not “wash off” as with regular pavements that shed water.
 - ▶ No salt should be applied for the first year on pervious concrete to protect the surface of the concrete.
 - ▶ Install skids or rollers on snow plows to raise blade slightly and avoid damage to permeable pavement.





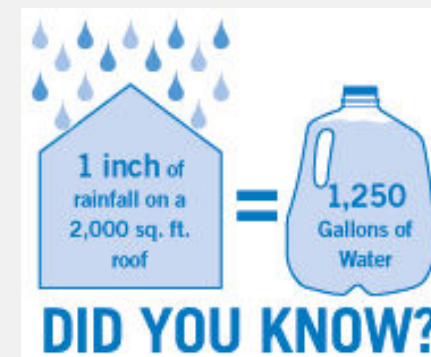
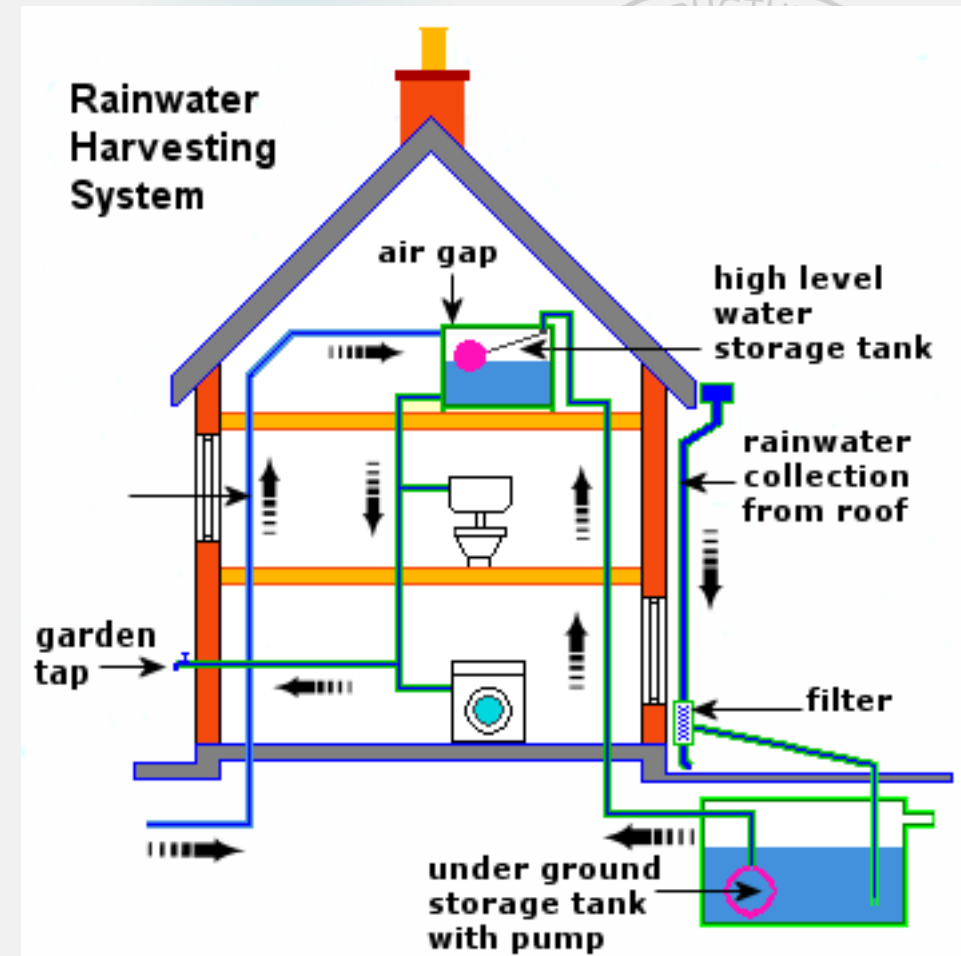
MODULE 8

Rainwater Harvesting



GENERAL OVERVIEW

- ▶ Rainwater harvesting systems (RHWs) collect water from a surface (usually a roof) for re-use within a building or for landscaping.
- ▶ Purpose may be to conserve water, retain/treat runoff, or re-use for other purposes.
- ▶ Rainwater harvesting is a stormwater practice that reduces the volume and rate of stormwater flow from impervious areas and associated impacts (e.g., erosion of stream channels) to receiving waters.



GENERAL OVERVIEW

RHW Types

- ▶ RHW systems come in many forms and sizes
 - ▶ Rain barrels
 - ▶ Above-ground tanks (cisterns)
 - ▶ Below-ground tanks (cisterns)



Above-Ground Cistern – foodsdirect.com



Below-Ground Cistern – PermaDesign

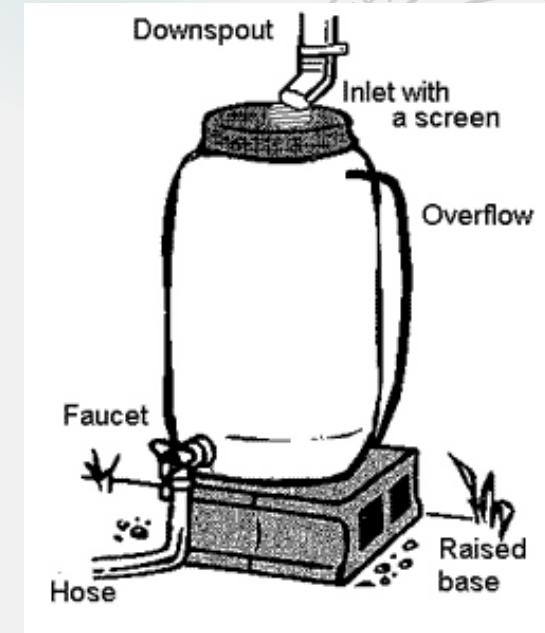


Rain Barrel - SUNY
Dept of Env. Science
and Forestry

GENERAL OVERVIEW

Rain Barrel Overview

- ▶ Generally used on residential properties
- ▶ Small amount of volume compared with cisterns
- ▶ Can “daisy chain” (connect) multiple barrels together for increased volume
- ▶ Basic components are:
 - ▶ Catchment area (where runoff comes from; roof)
 - ▶ Conveyance system (how water travels to barrel)
 - ▶ Storage tank (barrel)
 - ▶ Filtration (to screen out leaf and other debris)
 - ▶ Water distribution (where water is sent)
 - ▶ Normally for on-site irrigation
 - ▶ Overflow for large storms



Components of a Rain Barrel System – Environment Erie



Multi-Barrel System – Green Eye Co-op



Rain Barrel Screen - KSJD

GENERAL OVERVIEW

Cistern Overview

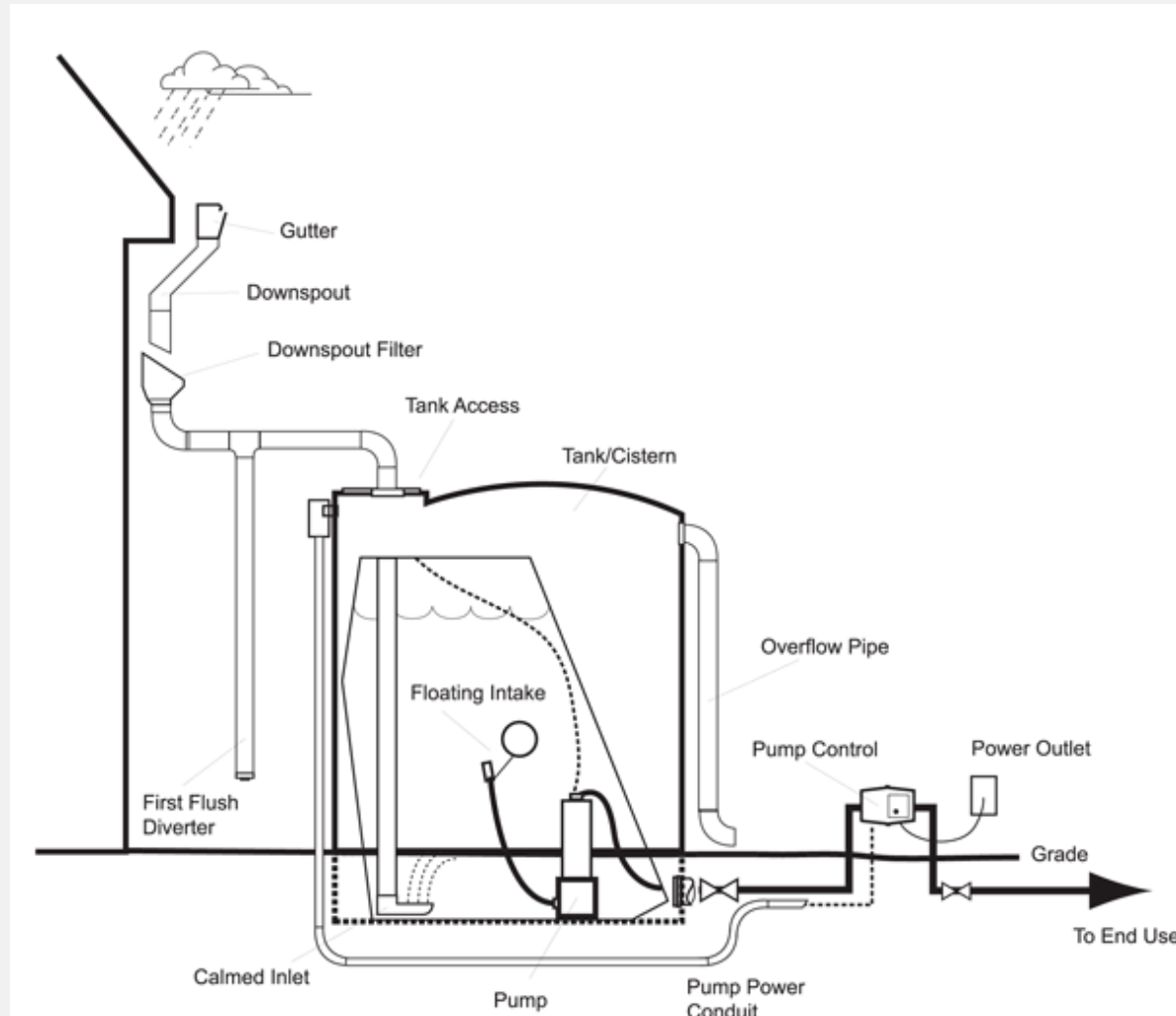


- ▶ Generally used on industrial and commercial properties
- ▶ Capture larger volumes compared with rain barrels
- ▶ More complex system than rain barrels
- ▶ Above-ground or below-ground



6500 gallon tank

Cistern Components



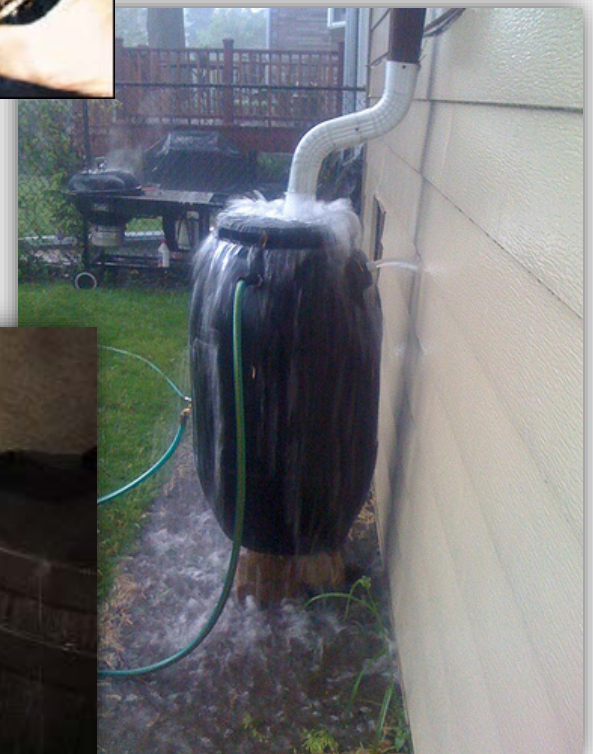
- ▶ Catchment area
- ▶ Conveyance system
- ▶ Storage tank
- ▶ Filtration
 - ▶ Normally a screen if used for on-site irrigation
 - ▶ Additional filtration for some uses
- ▶ Water distribution
 - ▶ Can be on-site irrigation or domestic use
 - ▶ Must have an overflow for large storms
 - ▶ Controlled through automation or passively

CISTERNS AND RAIN BARRELS

Basic Maintenance for Proper Function



- ▶ Structural problems:
 - ▶ Pipe joints disconnected
 - ▶ Barrel/cistern settling
- ▶ Leaks
- ▶ Performance issues:
 - ▶ Premature clogging of filters
 - ▶ Water quality (e.g. excess sediment/debris in rain barrel)
 - ▶ Inadequate supply



CISTERNS AND RAIN BARRELS

Basic Maintenance

- ▶ Remove organic material in source area (moss, leaves, etc.).
- ▶ Inspect and clean collection gutters and downspout filters.
- ▶ Inspect overall system integrity.
 - ▶ Check for sunlight intrusion into cistern.
 - ▶ Install and check insect/vermin screens.
- ▶ Inspect and clean membrane, ultraviolet light or other type of filters using manufacturer prescribed methods and frequency.
- ▶ Conduct winterizing (preparation for use in cold weather).
- ▶ Test filter and overflow alarms.
- ▶ Document maintenance.



CISTERNS AND RAIN BARRELS

Basic Maintenance



Tank maintenance frequency and methods:

- ▶ Cleaning methods will vary given system design, but maintenance for all systems should include:
 - ▶ Inspection and maintenance of backflow assemblies.
 - ▶ Protection from sunlight entering interior (reduce algae growth).
 - ▶ Maintenance of access points to prevent entry of vermin.
 - ▶ Maintenance of outlets a few inches above the bottom of the cistern.
 - ▶ Inspection and maintenance of overflow protection.
 - ▶ Chlorination of tank at prescribed frequency (e.g., quarterly).
 - ▶ Drainage and removal of sediment from tank bottom.
 - ▶ Drainage and cleaning of tank walls with chlorine solution at prescribed frequency.



MODULE 9

Rooftop Practices



GENERAL OVERVIEW

Green Roofs



- ▶ Vegetative layer that grows in specially-designed soil, which sits on top of a drainage layer
- ▶ Green roofs benefits:
 - ▶ Retain and detain stormwater
 - ▶ Reduce pollution
 - ▶ Conserve energy
 - ▶ Cool rooftop surfaces in hot climates
 - ▶ Create habitat

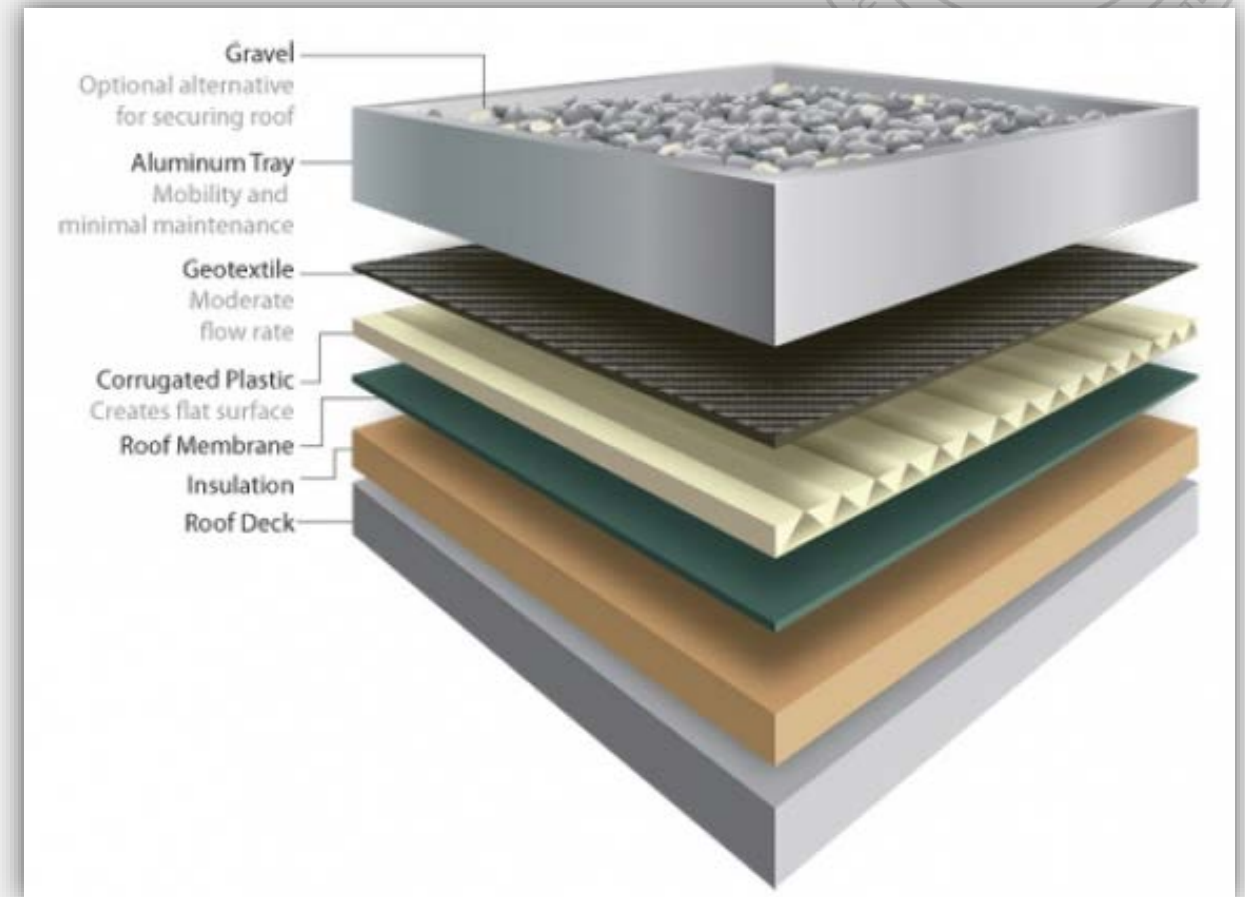


GENERAL OVERVIEW

Blue Roofs



- ▶ Non-vegetated systems that detain stormwater along weirs (check dams) at the roof drain inlets and gradually release stormwater
- ▶ Blue roofs benefits:
 - ▶ Retain and detain stormwater
 - ▶ Water storage for re-use
 - ▶ Rooftop cooling

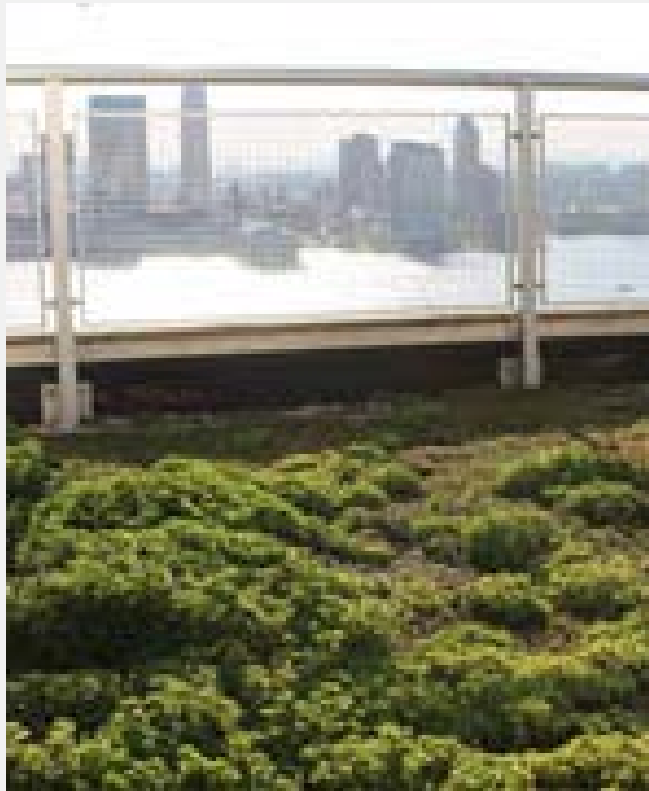


GREEN ROOFS

Types of Green Roofs



Extensive



Intensive



GREEN ROOFS

Types of Green Roofs

Extensive



Soil depth up to 6 inches

Lightweight

Limited plant species options

Lower maintenance, nutrient, and irrigation requirements

Intensive



Soil depth typically 6 inches or greater

Heavier weight load on roof

Many more plant options, including trees and shrubs

Requires irrigation, fertilization, and maintenance



GREEN ROOFS

Co-Benefits of Green Roofs

- ▶ Urban heat island reduction
- ▶ Usable green space
- ▶ Energy efficiency/thermal insulation
- ▶ Roof longevity
- ▶ Biodiversity/habitat
- ▶ Noise reduction
- ▶ Reduction of dust and smog particles
- ▶ Opportunities to integrate the green roof design into an aesthetic building design
- ▶ Aesthetics/views
- ▶ Food production



GREEN ROOFS

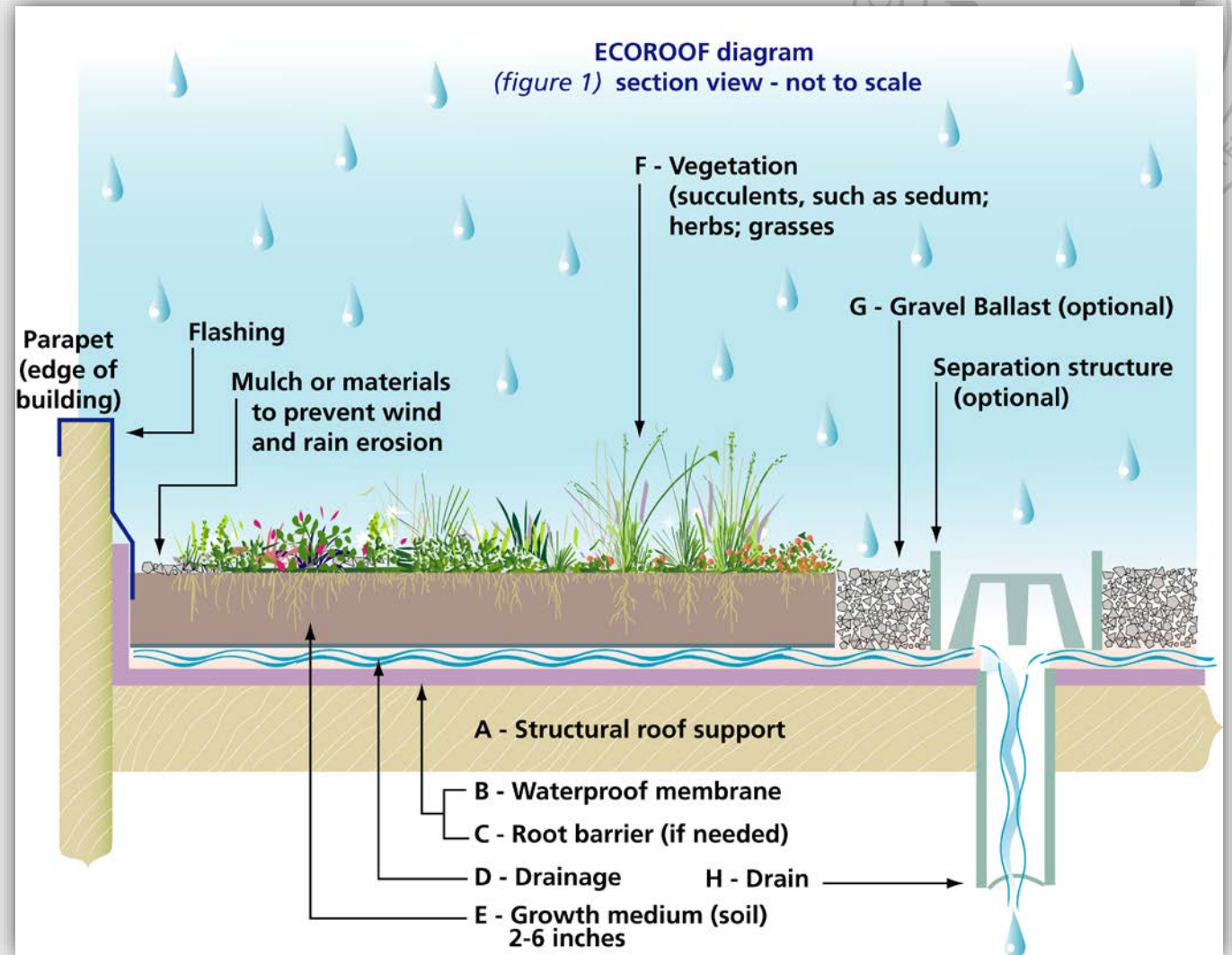
Green Roofs Examples



GREEN ROOFS

Components

- ▶ Vegetation/plants
- ▶ Growth media (soil)
- ▶ Filter layer
- ▶ Drainage layer
- ▶ Protection fabric
- ▶ Root barrier
- ▶ Insulation
- ▶ Waterproof membrane
- ▶ Edging/curbs
- ▶ Ballast/gravel
- ▶ Maintenance paths



GREEN ROOF Inspection



- ▶ Roof leaks (conducted by building inspector or roof contractor)
- ▶ Plant health, vigor, aesthetics (inspect for prescribed plant density)
 - ▶ May change significantly without regular maintenance
- ▶ Overall system integrity
- ▶ Loss of growing media (usually due to wind erosion)
 - ▶ Maintaining plant density important for erosion prevention
- ▶ Ponding and drainage
 - ▶ Use water rapidly
 - ▶ No ponding water



GREEN ROOF Inspection

- ▶ Bare/bald spots
 - ▶ General indication of poor functionality
- ▶ Red/brown foliage for sedums common during winter and very hot/dry conditions
 - ▶ Extended periods of red/brown cover may indicate need for irrigation or nutrient inputs



Red/Brown Foliage and Bare Spots – Enviromat, 2017



Bare Spots – Green Roof Technology, 2017



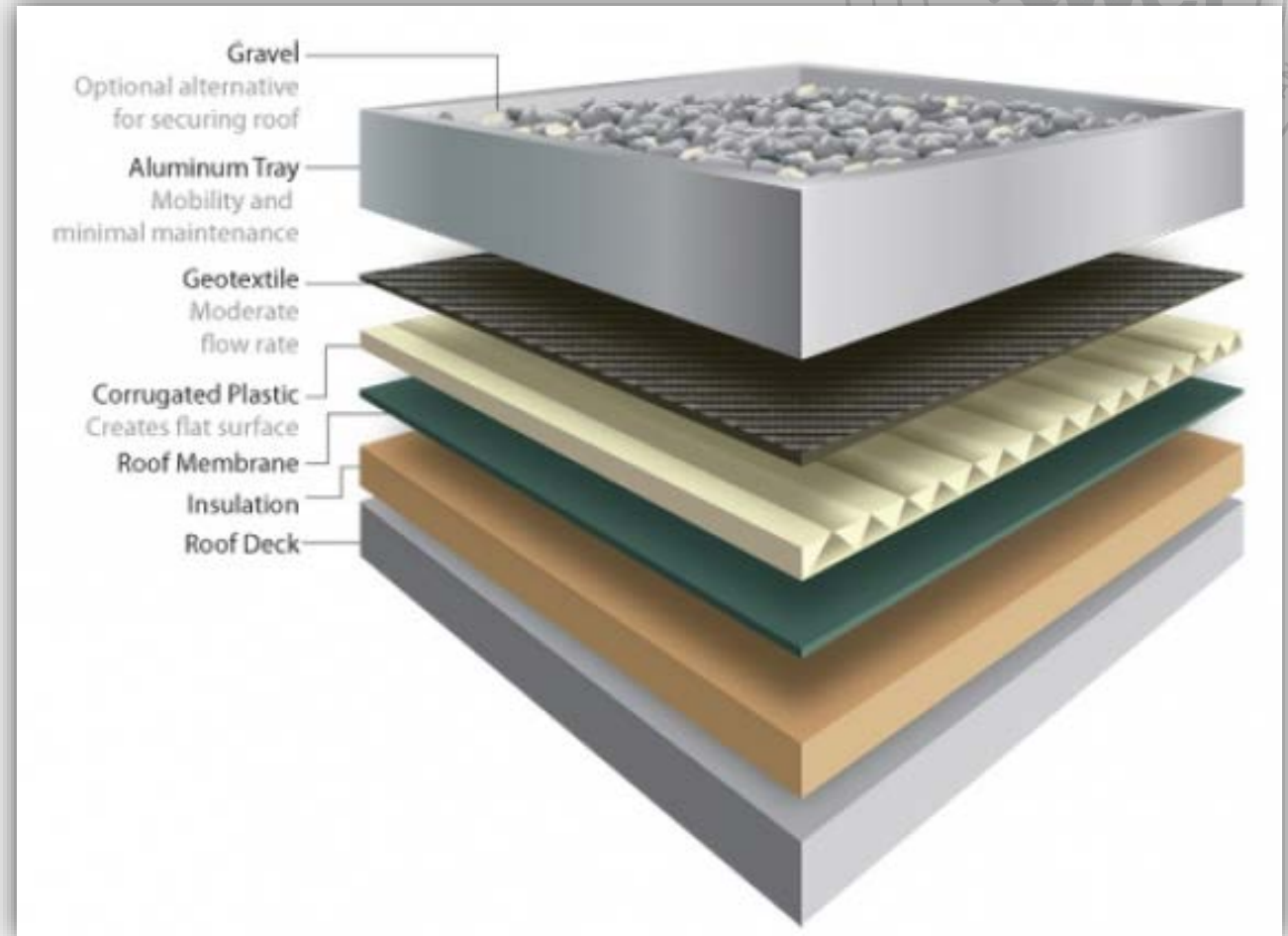
Bare Spots – Green Roof Technology, 2017



BLUE ROOFS

Components

- ▶ Filter media (optional)
- ▶ Decking/modular structure (optional)
- ▶ Membrane layer
- ▶ Passive controls
- ▶ Active controls

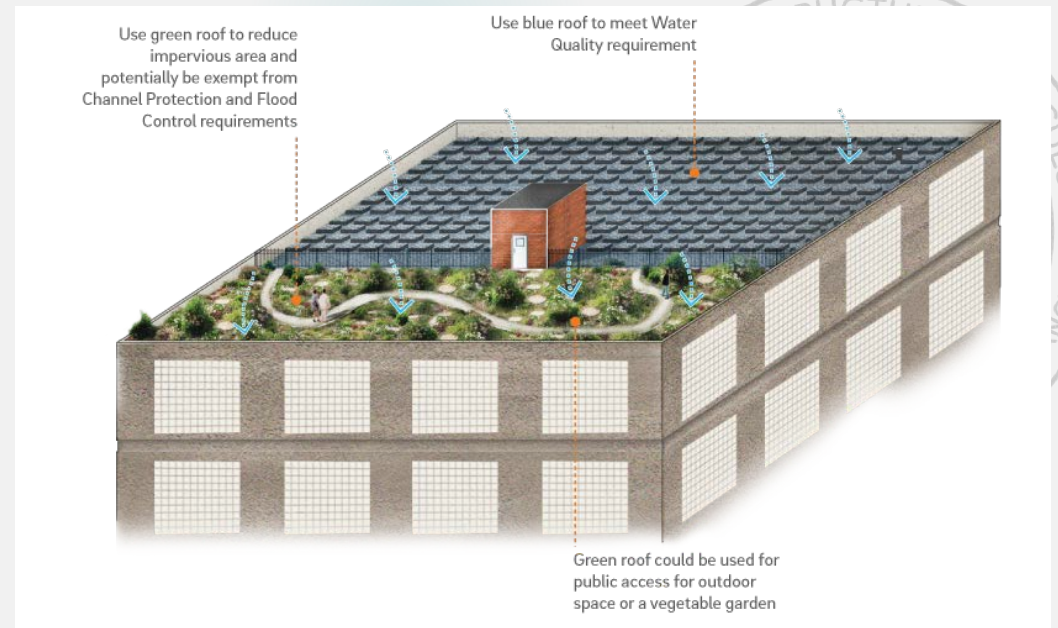


BLUE ROOFS

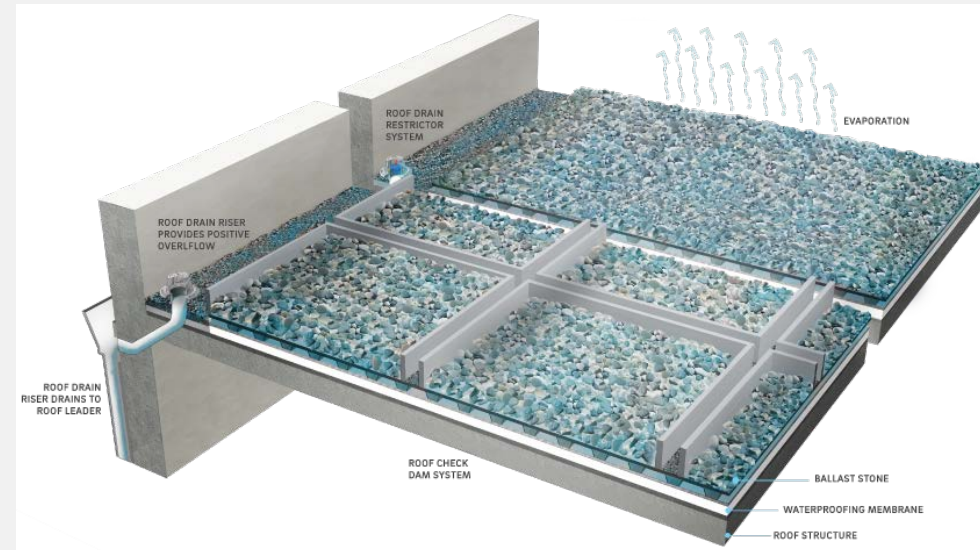
Components

▶ Green Roof vs. Blue Roof

- ▶ Blue roofs focus on water quality through capture/detention and filtration if a filter is provided.
- ▶ Green roof provides enhanced treatment through capture/infiltration-vegetative uptake as well as impervious cover reduction and additional benefits (reduction in urban heat island effect, air particulate treatment, etc.).



Green Roof and Blue Roof Diagram – Philadelphia Water Department, 2017



Blue Roof Diagram – Philadelphia Water Department, 2017

ROOFTOP PRACTICES

Blue Roof Examples



BLUE ROOF

Identify Signs Roof is Working Properly

- ▶ Roof leaks (conducted by building inspector or roof contractor)
- ▶ Overall system integrity
- ▶ Loss of media (if present)
- ▶ Damage to decking/modular structure (if present)
- ▶ Function of active controls (e.g., valves that control flow rate working as designed)
- ▶ Water quality (determined by water quality sampling plan)
- ▶ Ponding and drainage



BLUE ROOF

Operation and Maintenance



- ▶ Media intact (if present)
- ▶ Insect control (e.g., mosquito control)
- ▶ Structural components (decking or modular structure)
- ▶ Debris and litter removal
- ▶ Staff training and written guidance
- ▶ Access and safety plan
- ▶ Leak detection system operation check
- ▶ Snow and ice issues
 - ▶ Freeze-thaw/expansion damage
- ▶ Ponding and drainage issues
 - ▶ Excessive ponding at key times (e.g., after first storms when fall leaves may clog drains)



BLUE ROOF

Operation and Maintenance

- ▶ Develop and follow an activity matrix that provides:
 - ▶ Visible prompt for maintenance.
 - ▶ Scheduled prompts for maintenance (Maintenance Calendar).
- ▶ Develop O&M forms & system for documentation.





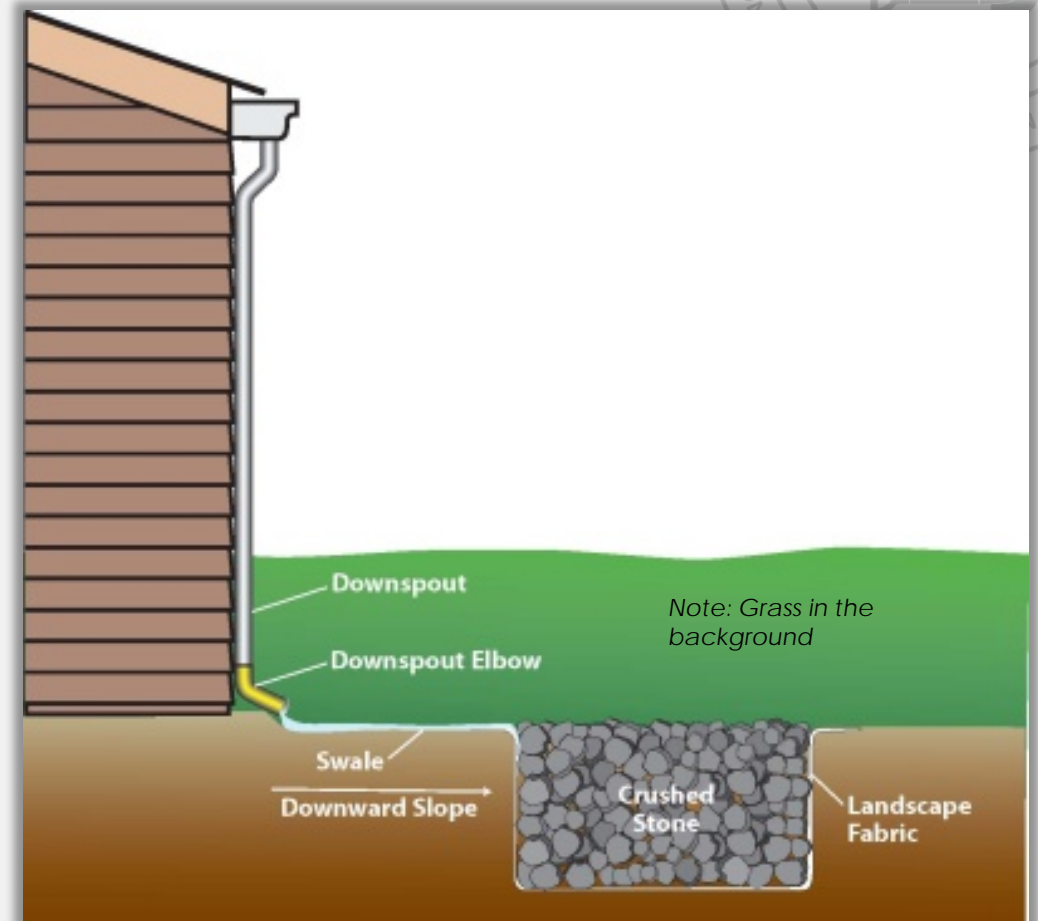
MODULE 10

Dry Wells



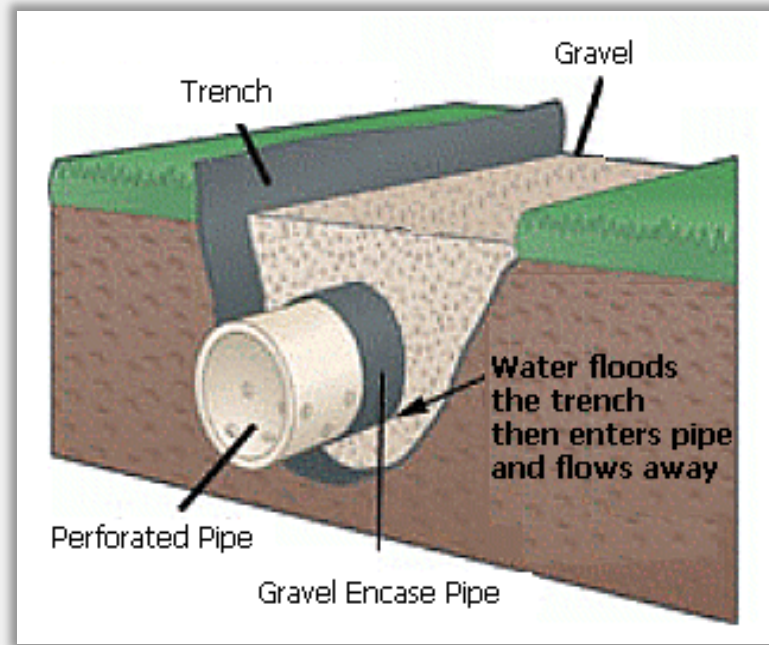
OVERVIEW

- ▶ Dry Wells: excavated depressions filled with uniformly graded washed rock that temporarily stores stormwater runoff until it infiltrates into the underlying soils.
- ▶ Dry wells may also need to follow Underground Injection Control (UIC) regulations for protection of groundwater quality.
 - ▶ This may involve the installation of a pretreatment facility (a stormwater facility preceding the dry well that would discharge or drain to the dry well).



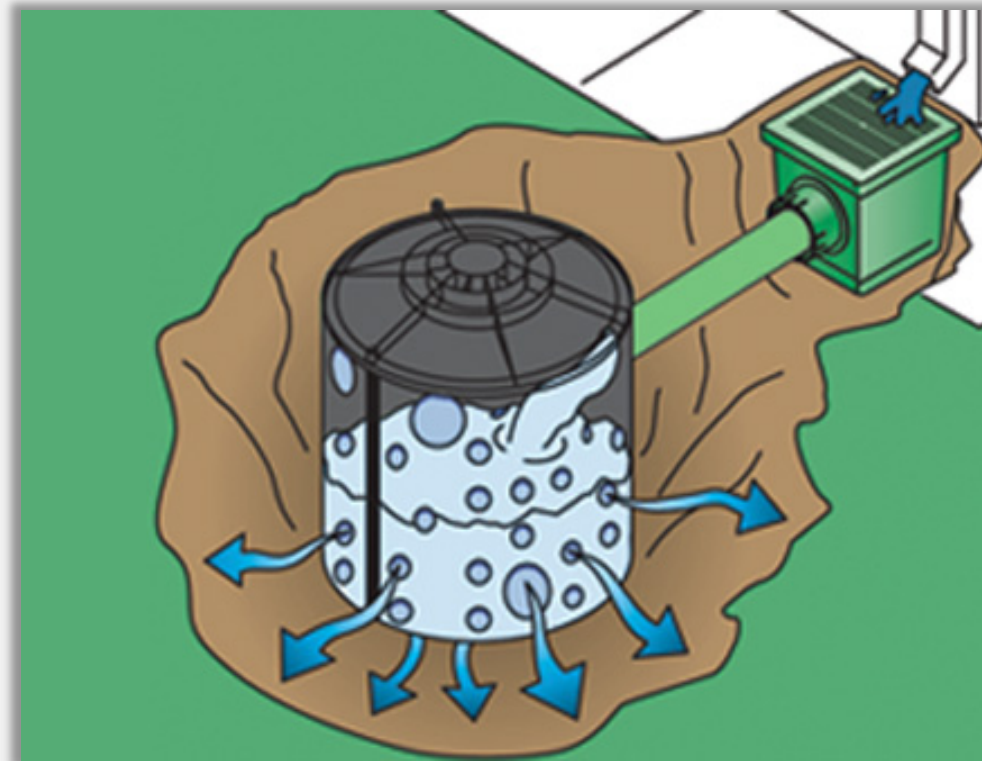
OVERVIEW

- ▶ Infiltration Trench: similar to dry wells, but they are designed as linear surface or subsurface facilities rather than vertical surface or subsurface facilities.



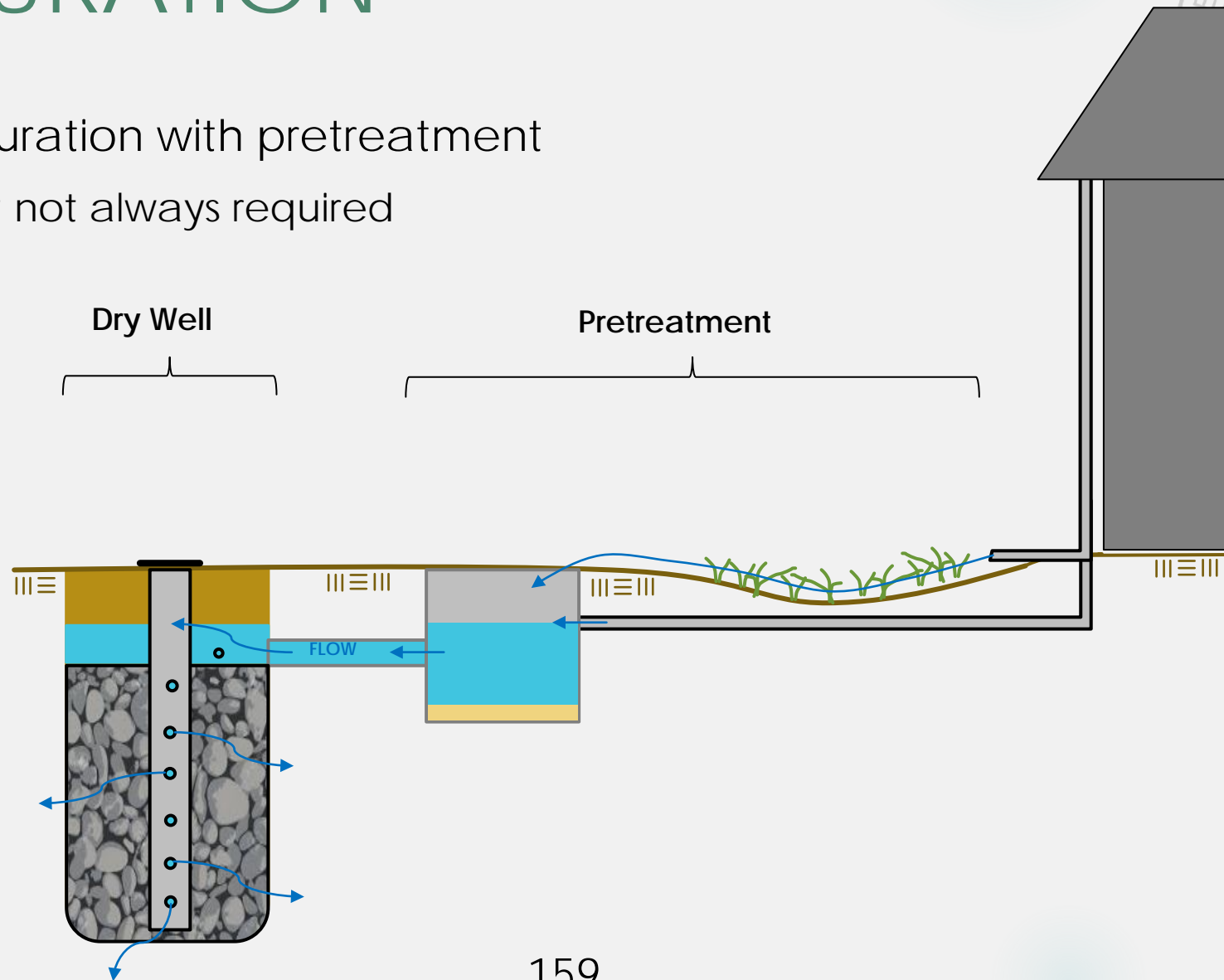
CONFIGURATION

- ▶ Dry wells are typically connected to roof downspouts either directly or via a yard drain (small catch basin installed in a lawn). Runoff from parking lots, roadways, and driveways can also be directed to a dry well.



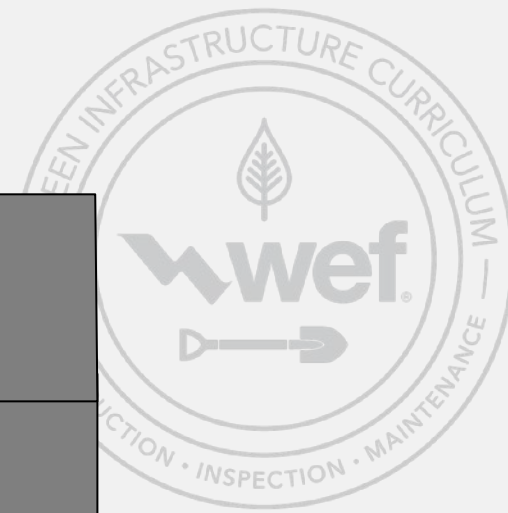
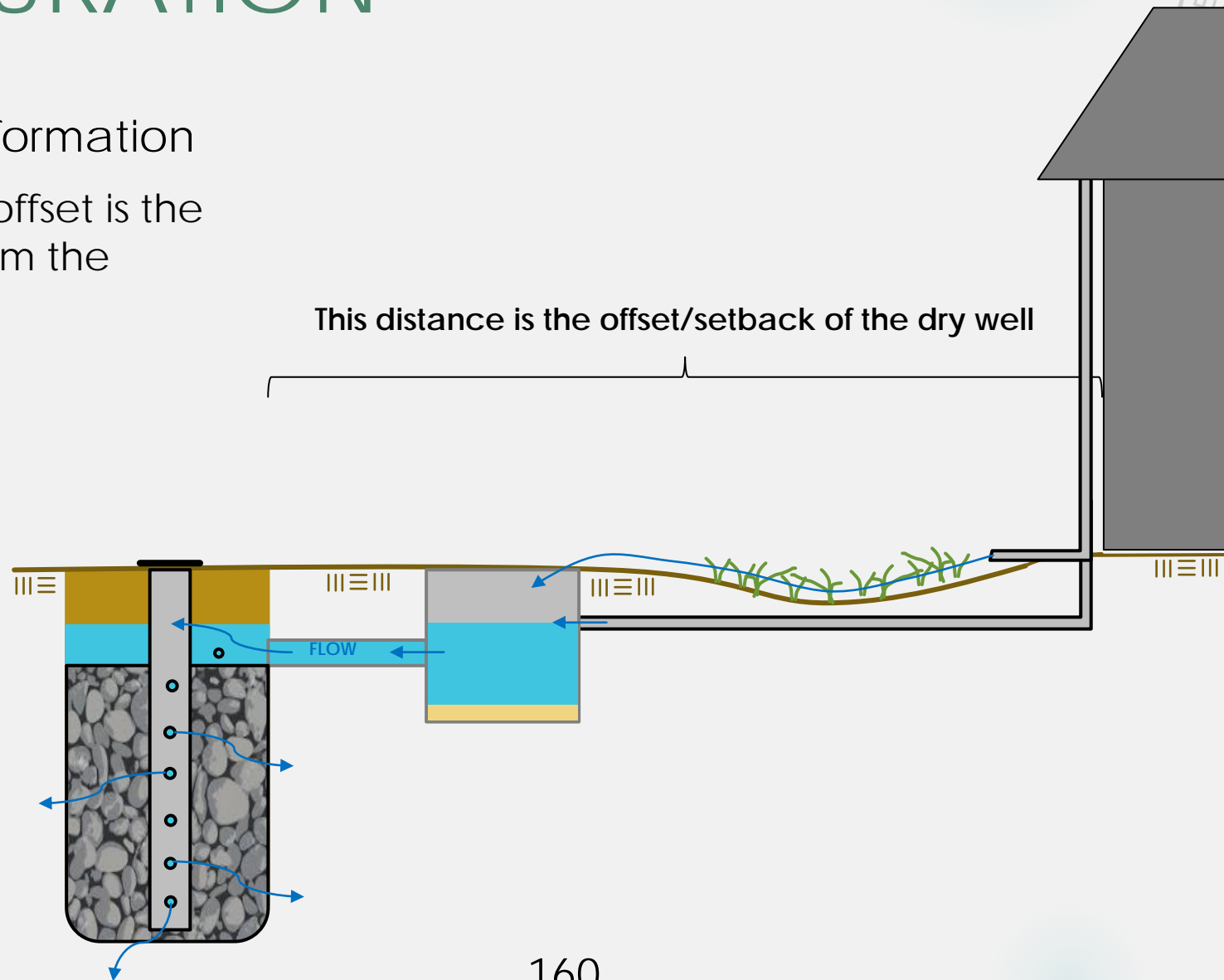
CONFIGURATION

- ▶ Dry well configuration with pretreatment
 - ▶ Pretreatment not always required



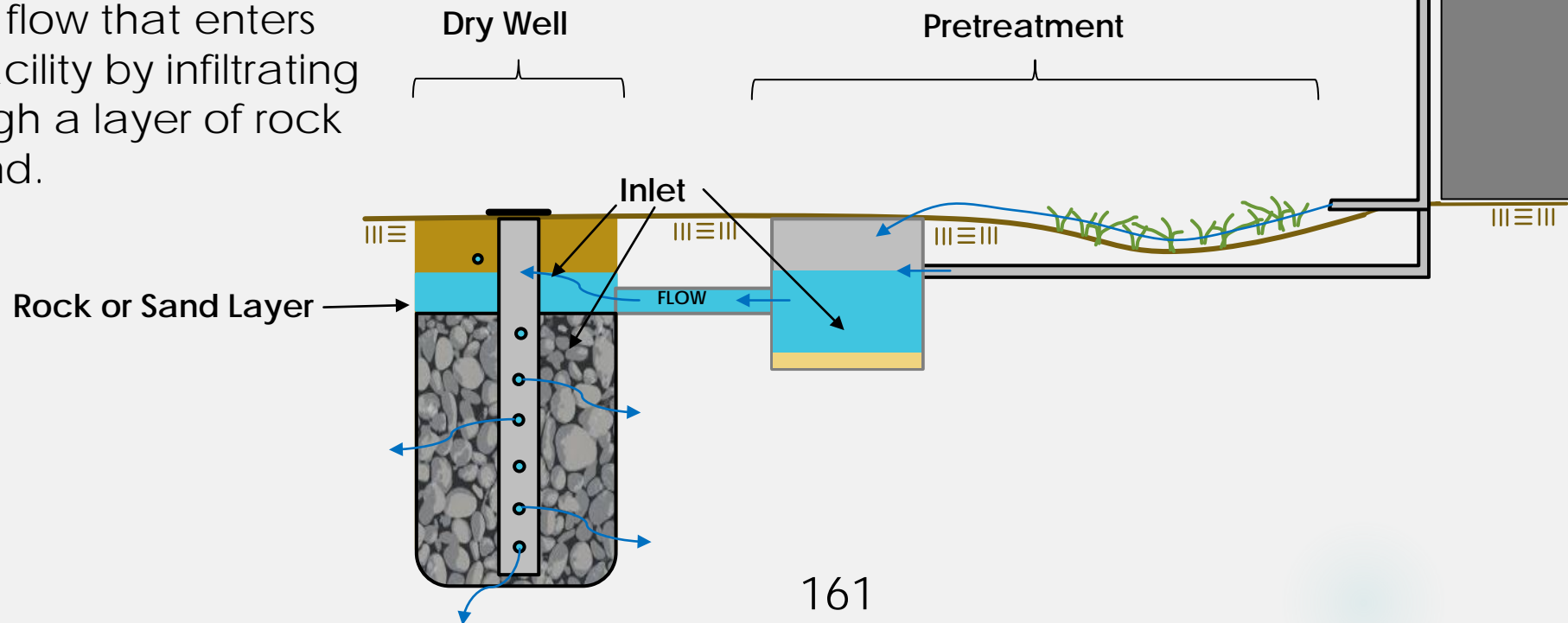
CONFIGURATION

- ▶ Key lay-out information
 - ▶ Setback or offset is the distance from the building.



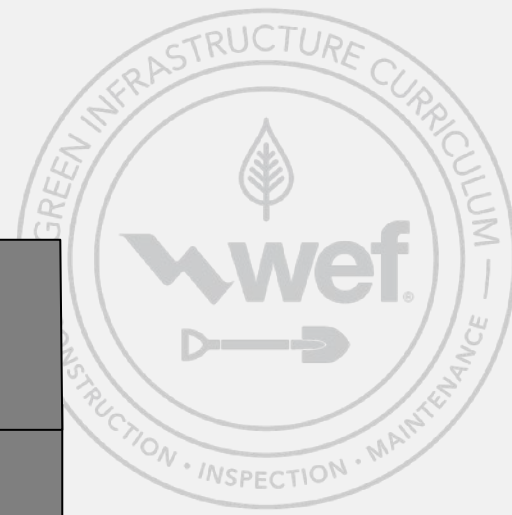
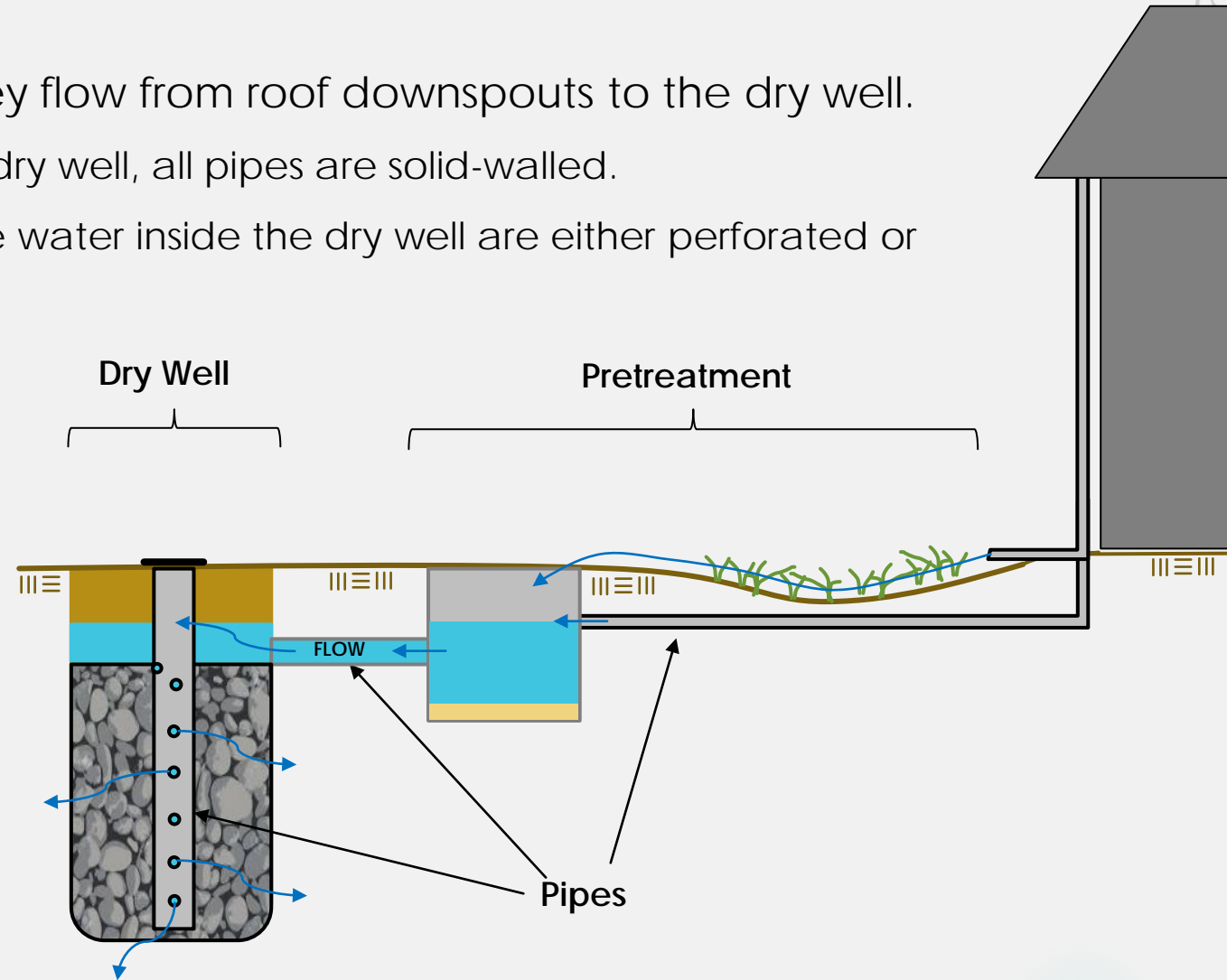
CONFIGURATION

- ▶ Inlet: Stormwater runoff is typically routed to a dry well with a solid-wall pipe and then distributed into the drain rock bed using a perforated or slotted pipe.
- ▶ Some dry wells are designed to receive sheet flow that enters the facility by infiltrating through a layer of rock or sand.



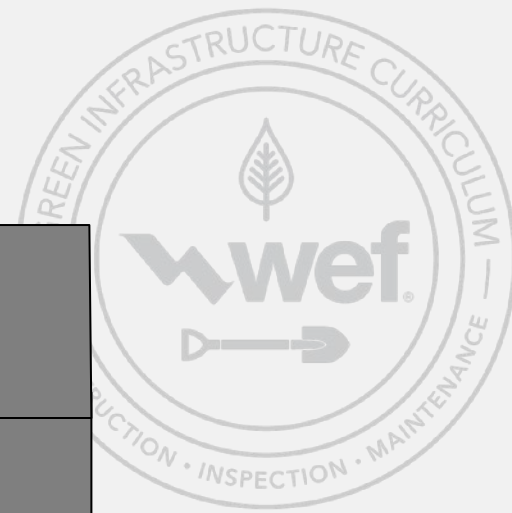
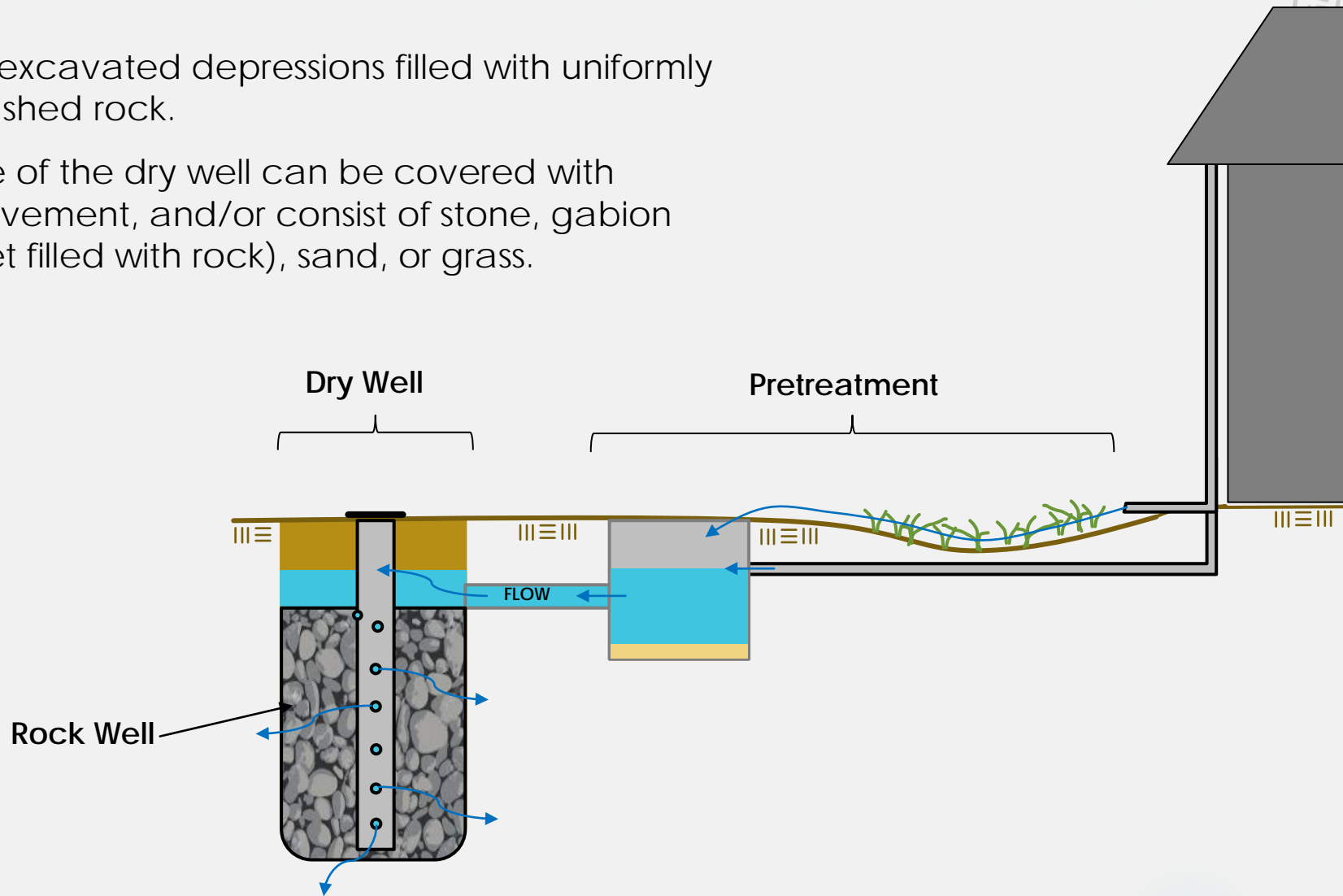
CONFIGURATION

- ▶ Pipes: used to convey flow from roof downspouts to the dry well.
 - ▶ Leading up to the dry well, all pipes are solid-walled.
 - ▶ Pipes that distribute water inside the dry well are either perforated or slotted pipes.



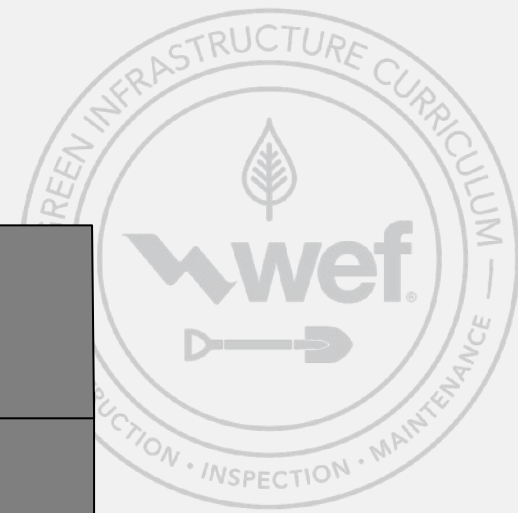
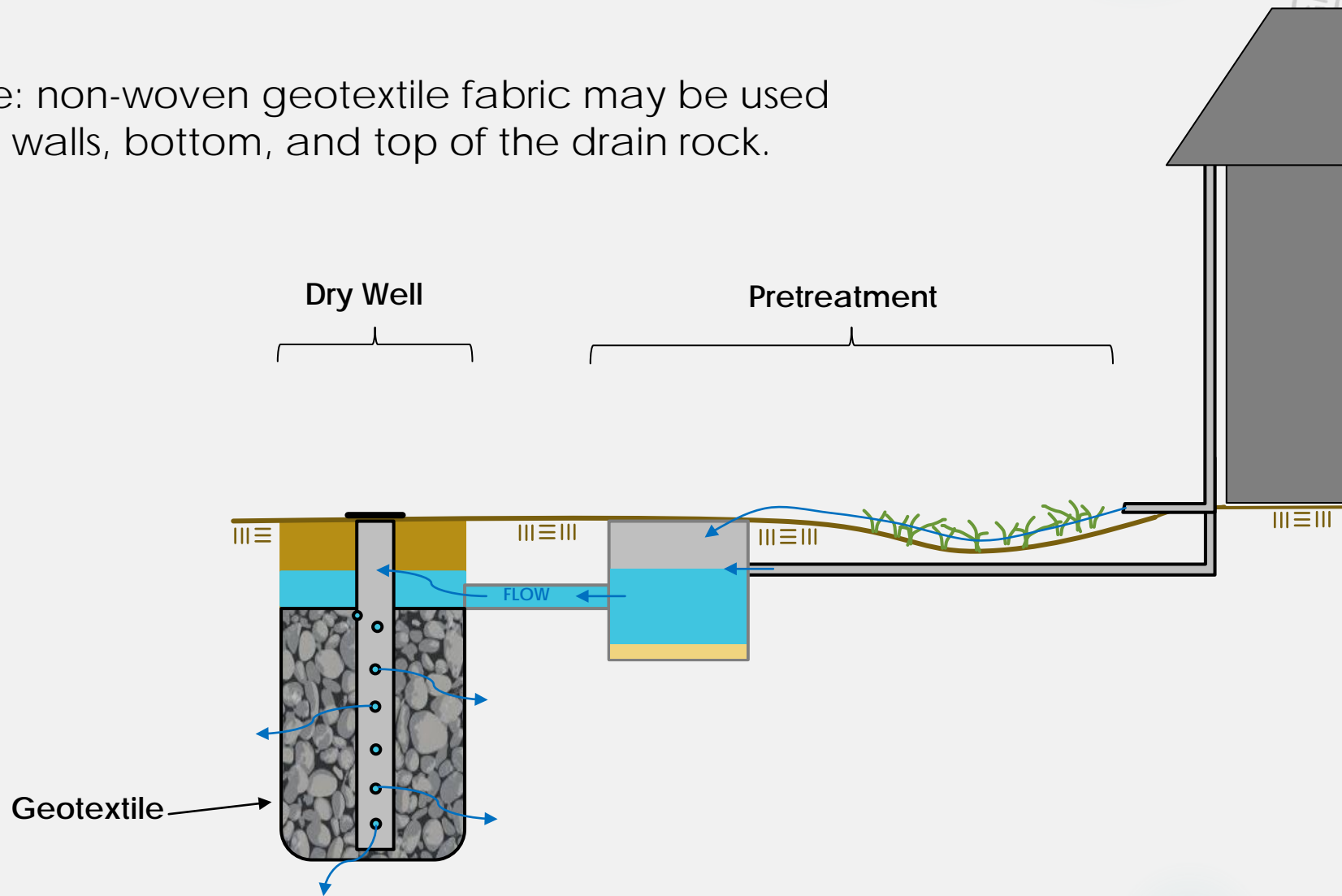
CONFIGURATION

- ▶ Rock Well: excavated depressions filled with uniformly graded washed rock.
- ▶ The surface of the dry well can be covered with grating, pavement, and/or consist of stone, gabion (wire basket filled with rock), sand, or grass.



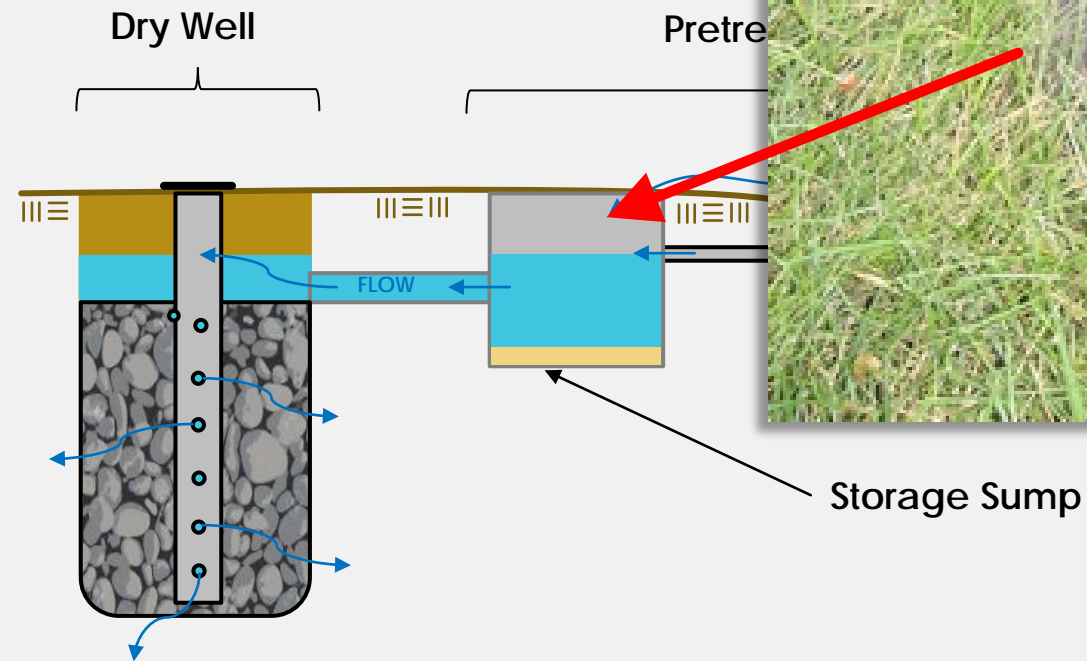
CONFIGURATION

- ▶ Geotextile: non-woven geotextile fabric may be used along the walls, bottom, and top of the drain rock.



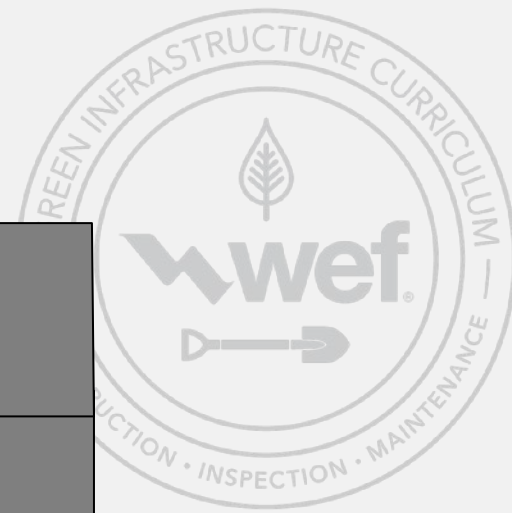
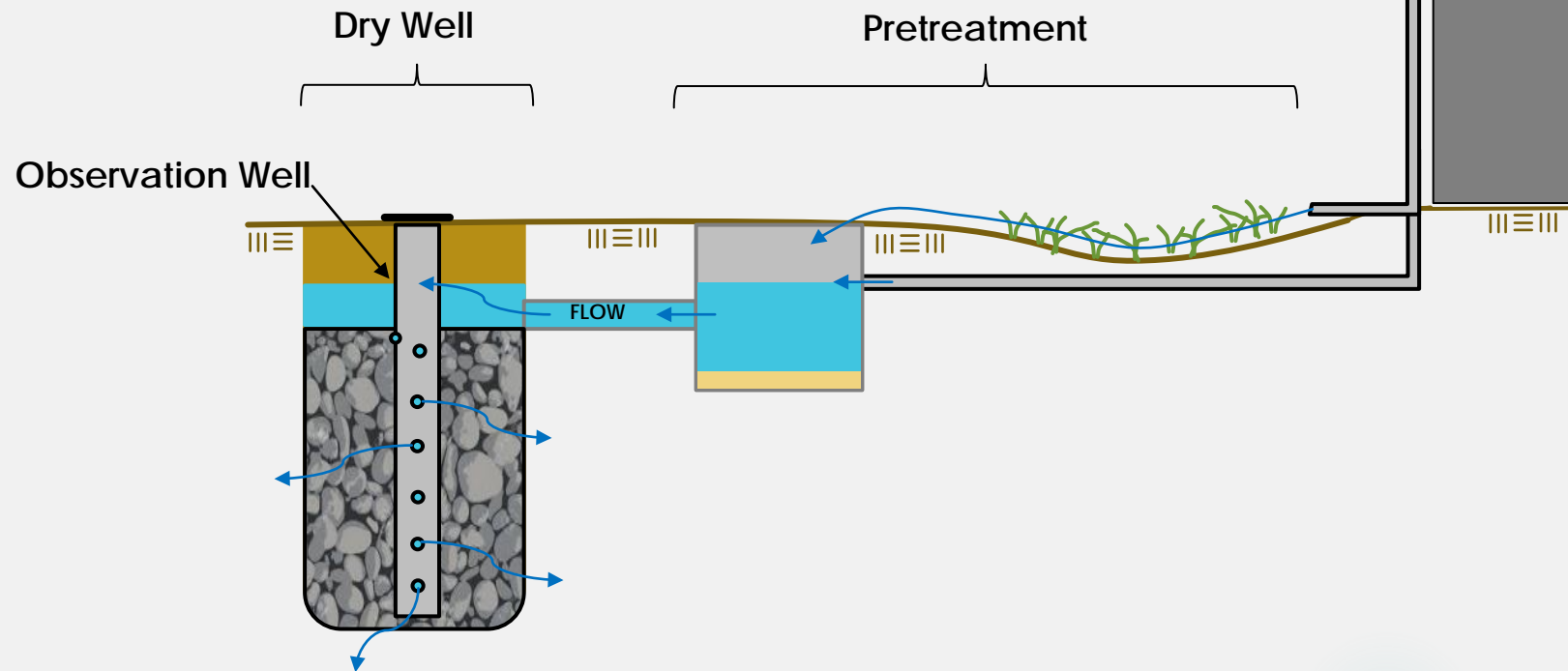
CONFIGURATION

- ▶ Storage Sump: settles out particulates from inflow (for concentrated flows).
- ▶ Concentrated flows must be distributed into the aggregate using a perforated or slotted subsurface pipe.

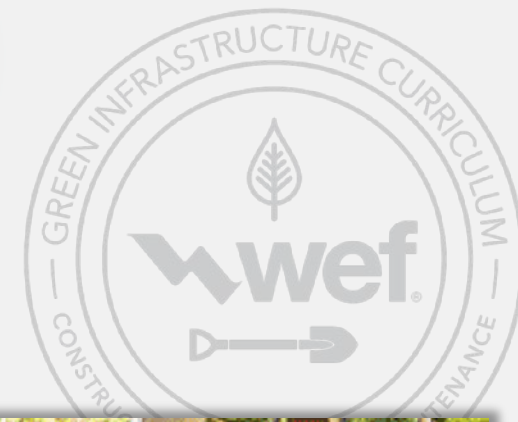


CONFIGURATION

- ▶ Observation Well: allows inspection of the rock in the dry well.
 - ▶ Some facilities have an observation well that allows monitoring of the water levels in rock beds to determine if the facility is draining properly.



INSTALLATION



- ▶ Protection
 - ▶ Prevent soil compaction at the proposed dry well location.
 - ▶ Protect the surface inlet from stockpiles of landscaping materials (e.g., mulch, soil, compost).
 - ▶ Prevent discharge of debris to the dry well from construction activities.
 - ▶ Prevent discharges from areas with high levels of pesticide/fertilizer use and high nutrient inputs (golf courses, sport fields, cemeteries, commercial composting, animal handling, nurseries).
 - ▶ Stabilize adjacent landscaped areas to avoid runoff mobilizing soil into the surface inlet.



INSTALLATION



- ▶ Excavation
 - ▶ Place excavated materials a safe distance from the dry well to ensure wall stability.
 - ▶ OSHA states that materials should be stored at least 2 feet away from the edges of the excavation.
 - ▶ Keep excavated materials away from slopes, neighboring property, sidewalks and streets. Cover excavated materials with plastic.



INSTALLATION



- ▶ Aggregate Placement and Compaction
 - ▶ Place rock in lifts and compact using plate compactors.
 - ▶ In general, a maximum loose lift thickness of 12 inches is recommended.
 - ▶ Prevent soils from mixing with the rock.





MODULE 11

Stormwater Wetlands



OVERVIEW



What are stormwater wetlands?

- ▶ Constructed treatment systems built to mimic natural wetland processes that use wetland vegetation, soils, and their associated bacteria and other microscopic plants and animals to improve water quality

Source: US EPA

<https://www.epa.gov/wetlands/constructed-wetlands>



OVERVIEW

Stormwater Wetland Functions

Stormwater wetlands are:

- ▶ Constructed to act like natural wetlands (store and filter water, support healthy wetland vegetation and animals and replenish local groundwater).
- ▶ Usually built outside of floodplains where natural wetlands occur and include control structures (e.g., pipes and catch-basins) to control the water level and rate of flow in and out of the facility.

Resource: EPA's "Constructed Treatment Wetland" two-page summary of how the facilities work, how they are built, and design considerations.

<https://nepis.epa.gov/Exe/ZyPDF.cgi/30005UPS.PDF?Dockey=30005UPS.PDF>.



OVERVIEW

Stormwater Wetland Functions



Stormwater wetlands can:

- ▶ Store water and thereby reduce stormwater volume and peak flows to protect streams and natural wetlands from erosion.
- ▶ Improve water quality by:
 - ▶ Slowing water to settle out sediment.
 - ▶ Filtering sediment and debris through plants.
 - ▶ Providing contact to allow contaminants to adsorb (attach) to minerals and organic matter.
 - ▶ Taking up nutrients through plants.
 - ▶ Chemically breaking down contaminants by bacteria.



OVERVIEW

Stormwater Wetland Functions

Where do these functions occur in wetlands?



1. Dissipate stormwater energy that can cause erosion.
2. Replenish groundwater.
3. Break down contaminants with plants and microorganisms.

OVERVIEW

Stormwater Wetland Functions

Where do these functions occur in wetlands?



4. Store water in the soil and allow some of it to slowly infiltrate into the groundwater.
5. Filter out sediment.
6. Provide plant and animal habitat.

OVERVIEW

Stormwater Wetland Functions

Where do these functions occur in wetlands?



7. Slowly release water to surrounding water bodies.
8. Temporarily hold water in basin.
9. Provide food for animals living in receiving waters.

OVERVIEW

Wetland Vegetation

Vegetation Types

▶ Submerged

- ▶ Plants entirely submerged under water except for flowering portions of plants; include Pondweed, Water Milfoil, Water Nymph

▶ Floating

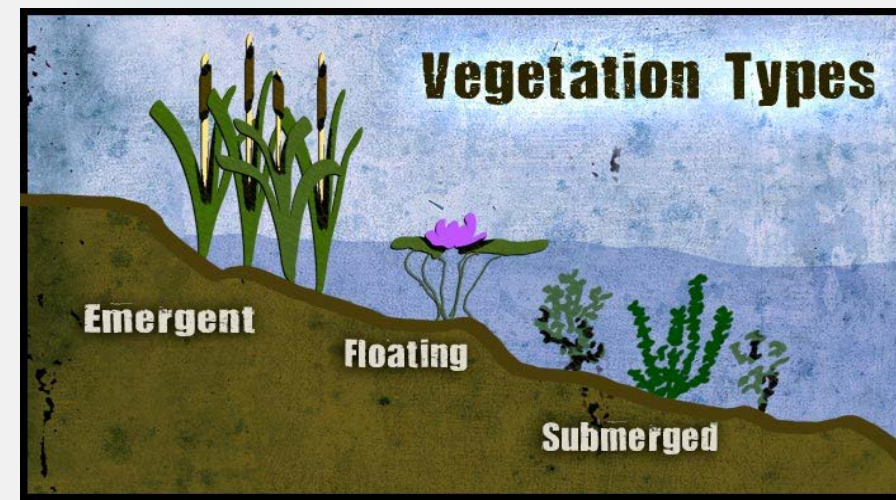
- ▶ Plants that have no roots and true stems, only leaves and flowers floating on or near the water surface; include Common Duckweed, Northern Watermeal, Watershield

▶ Floating-leaved

- ▶ Plants rooted in sediment but also have leaves and flowers that float on the water surface; include Yellow Pond Lily, Hairy Water Clover, American Water Lily

▶ Emergent

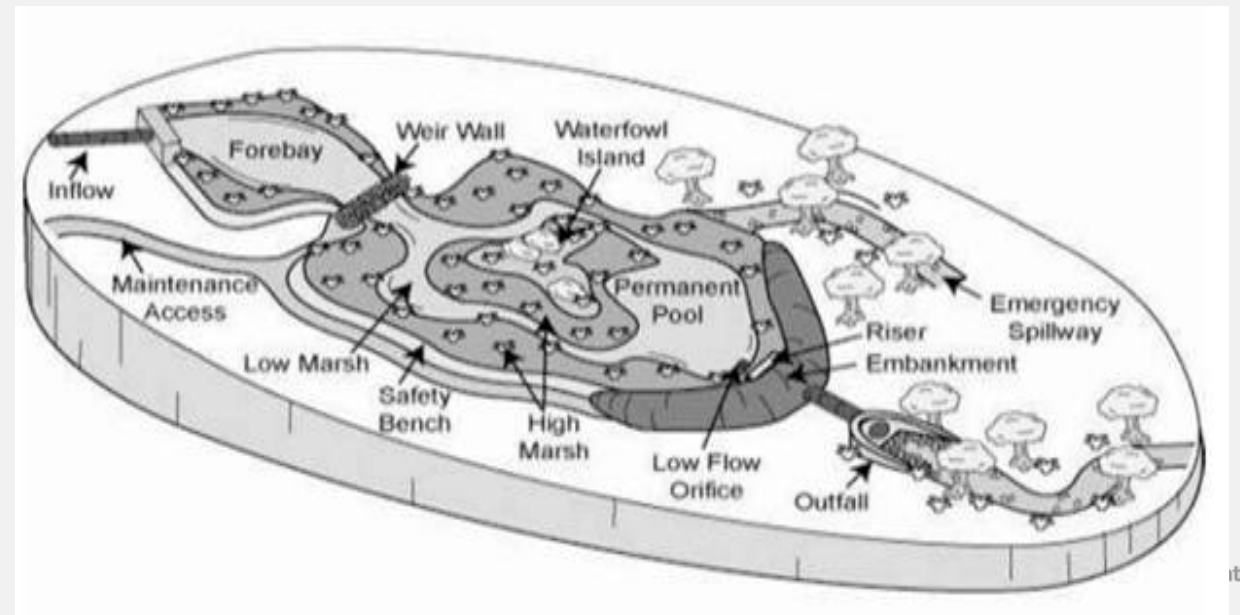
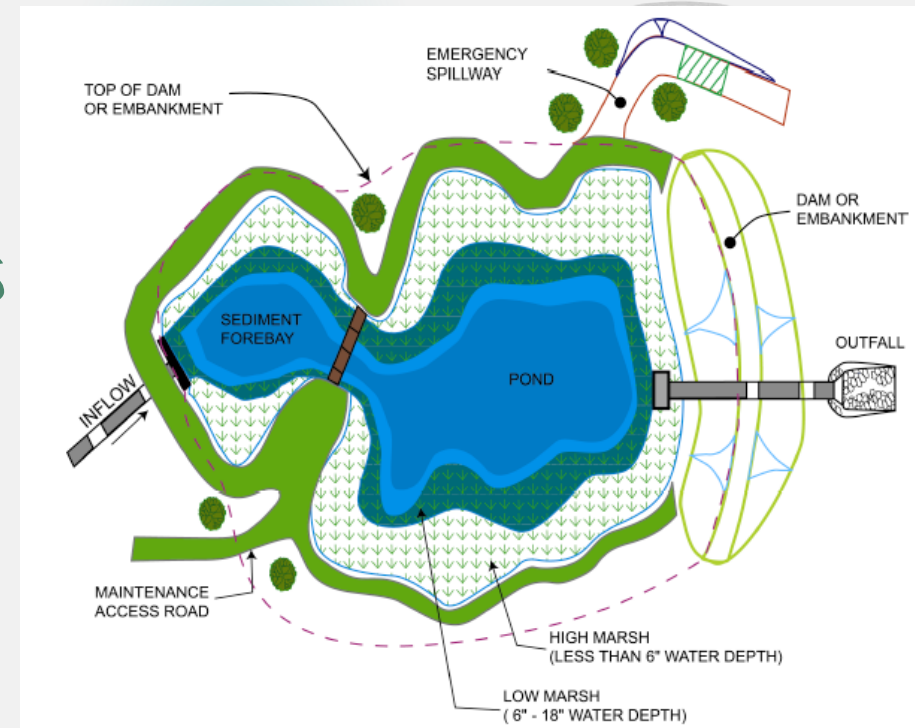
- ▶ Herbaceous and woody plants that grow with their bases submerged and rooted in inundated sediment or seasonally saturated soils; include Arrowhead, Common Buttonbush, American Lotus, Poison Sumac



BASIC CONSTRUCTION

Constructed Wetland Components

- ▶ Inlets deliver water into the wetland.
- ▶ Forebays capture sediment.
- ▶ Pipes or weirs distribute water across the wetland.
- ▶ Ponding areas include a combination of emergent and submergent vegetation zones.
 - ▶ Facilities may also have detention ponding built within them.
- ▶ Outlets (including emergency overflow) convey water out of facility and may control water level.





MODULE 12

Basics of Managing GI for Long Term Performance



RECORD DRAWINGS



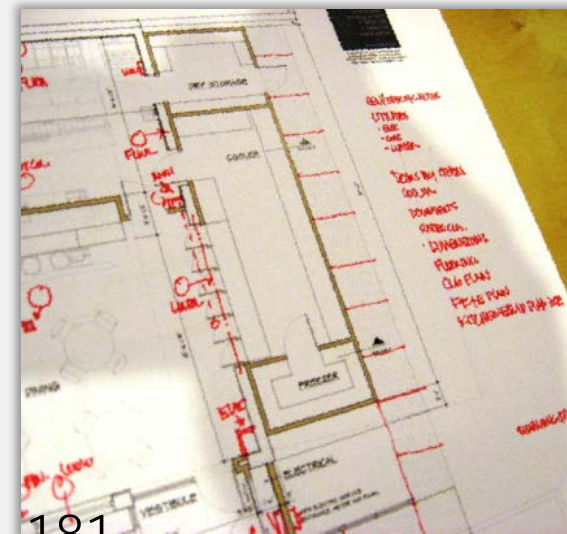
- ▶ What are record drawings?
 - ▶ A revised set of drawings submitted by a contractor upon the completion of a project or job
 - ▶ Reflect all changes made in the specifications and working drawings during the construction process
 - ▶ Often called "as-built drawings" or "as-builts"
 - ▶ Usually stamped and signed by a professional engineer
 - ▶ Good reference to help determine the size and location of the components of your stormwater system



RECORD DRAWINGS



- ▶ What do they contain?
 - ▶ Exact dimensions, geometry, and location of all elements of the work completed under contract
- ▶ When would you refer to them?
 - ▶ During construction inspections
 - ▶ During maintenance inspections to verify initial conditions when the project was completed



DOCUMENTATION

Operations and Maintenance Plan



- ▶ What is an Operation and Maintenance (O&M) plan?
 - ▶ A technical manual written by an engineer containing specific directions on how to best maintain a stormwater system for optimum long-term performance
 - ▶ Should be used as your primary reference on how to best inspect and maintain your stormwater system



DOCUMENTATION

Photo Documentation

Used to determine if elements of a project are installed properly (construction) or conditions of a facility and tasks performed for O&M.

Record the following:

- ▶ Time
- ▶ Date
- ▶ Description
- ▶ Exact location
- ▶ Typical photo documentation elements to consider:
 - ▶ Viewer's perspective
 - ▶ Prop to provide reference for relative size of feature of interest (e.g., person, hard hat, etc.)
 - ▶ Landmark to show the location of GI practice
 - ▶ Consistent naming convention for photos (i.e., date-name of GI facility-title)



DOCUMENTATION

Photo Documentation

- ▶ Typical photo documentation includes (but is not limited to):
 - ▶ Examples for construction inspection:
 - ▶ Temporary erosion and sediment control practices
 - ▶ Infiltration test pit placement
 - ▶ GI practice underdrain placement, mulch, and plantings
 - ▶ Permeable pavement infiltration test placement
 - ▶ Examples for O&M:
 - ▶ Condition of GI practice inlets/outlets and overflow areas
 - ▶ Vegetation health/condition



INSPECTION REPORTS



- ▶ Importance of inspection report documentation:
 - ▶ Verify construction elements are properly installed.
 - ▶ Track condition before and after maintenance activities.
 - ▶ Track long-term condition of facilities to refine the level of effort to maintain proper functioning condition.
 - ▶ Track inspection and maintenance needs to determine resources (funding and staff) necessary to maintain facilities at proper functioning condition.
 - ▶ Determine optimum timing to maintain facilities in proper functioning condition.
 - ▶ Document inspection and maintenance for regulatory compliance.



MODULE 13

Conclusion



Stormwater Management Green Infrastructure



Common Terms – this time, YOU define:

- ▶ Background
 - ▶ Green Infrastructure
 - ▶ Gray Infrastructure
 - ▶ Stormwater Runoff
 - ▶ Urbanization
 - ▶ Watershed
 - ▶ Impervious Surface
 - ▶ Retention Practice
 - ▶ Infiltration
- ▶ GI Practices
 - ▶ Bioretention Facility
 - ▶ Bioswale
 - ▶ Permeable Pavement
 - ▶ Green Roof
 - ▶ Blue Roof
 - ▶ Dry Well
 - ▶ Rainwater Harvesting
 - ▶ Constructed Stormwater Wetland
- ▶ Advanced
 - ▶ Hydrologic Cycle
 - ▶ Aquifer
 - ▶ Geotextile
 - ▶ Erosion
 - ▶ Mulch
 - ▶ Native/Invasive Vegetation
 - ▶ No. 57 stone

Module Review

Module 1 - Introduction to Stormwater and Green Infrastructure



The learning objectives for this module are:

- ▶ Basic concepts underlying watersheds and stormwater management
- ▶ Key concepts of basic hydrology/hydrologic function
- ▶ Basic environmental benefits of stormwater management
- ▶ Various approaches for managing stormwater
- ▶ Objectives of green infrastructure
- ▶ Terminology used to describe various GI practices

Module Review

Module 2 - Materials Used in Green Infrastructure



The learning objectives for this module are:

- ▶ Recognize the purpose of common GI construction materials.
- ▶ Understand the characteristics of soil and aggregates and why those characteristics are important to the proper function of various GI technologies.
- ▶ Understand how compaction occurs and how to achieve it or avoid it, as required.
- ▶ Identify different tools used to test soil compaction and explain how they work.
- ▶ Identify basic types of geosynthetic materials and understand the purpose for using them in GI.

Module Review

Module 3 - Vegetation Used in Green Infrastructure



The learning objectives for this module are:

- ▶ The purpose of vegetation in green infrastructure (GI)
- ▶ The specific functions and needs of trees, shrubs and groundcovers in GI facilities
- ▶ Key information needed for site design and species selection, and the key components in a vegetation/planting plan
- ▶ The function of soil/growing media for various facility types and the relationship of each type of media to vegetation in GI
- ▶ Best practices to transport and store vegetation on site
- ▶ The basics of plant establishment, health, and long-term maintenance
- ▶ General watering requirements of plants in GI facilities

Module Review

Module 4 – Safety Issues in Green Infrastructure



The learning objectives for this module are:

- ▶ Identify potential hazards on a GI site.
- ▶ Lower risk from working around overhead and buried utilities.
- ▶ Manage traffic and pedestrian hazards.
- ▶ Work safely in and around excavations and with heavy equipment.
- ▶ Work safely in confined spaces.
- ▶ Reduce risks such as slips, trips and falls.
- ▶ Lower risks from working outside – weather extremes, presence of insects, snakes, etc.

Module Review

Module 5 – Green Infrastructure Site Management



The learning objectives for this module are:

- ▶ Explain critical site management goals during the construction of a GI project.
- ▶ Explain critical site management goals after the practice is fully constructed and in operation.
- ▶ Identify the basic goals and practices of proper erosion and sediment control.
- ▶ Identify survey/layout markings and explain the purpose and method of protecting survey markings, layout stakes, etc.
- ▶ Identify site management activities that improve overall safety.
- ▶ Explain ways to manage stockpiled materials to prevent mixing and cross-contamination.
- ▶ Describe how excavation and compaction occur on a GI site.
- ▶ Explain the fundamentals of how to read and use site plans, section drawings and specifications.

Module Review

Module 6 – Bioretention



Understand the components and function of bioretention facilities in various forms:

- ▶ Bioretention cells and swales
- ▶ Rain gardens
- ▶ Vegetated curb extensions
- ▶ Bioswales/vegetated swales
- ▶ Bioretention planters
- ▶ Tree trenches

Module Review

Module 6 – Bioretention



Understand the basics of bioretention facility construction, maintenance and testing:

- ▶ Identify potential site safety hazards and the proper personal protective equipment (PPE) to reduce risks in bioretention practices.
- ▶ Read & comprehend basic information on engineering & construction drawings/plans.
- ▶ Recognize how to manage other utilities in and nearby bioretention practices.
- ▶ Understand the significance of & identify the procedures for stormwater management during construction.
- ▶ Recognize the significance & identify the procedures for the proper storage and handling of materials.
- ▶ Understand the schedule, primary inspection activities and how to use an inspection checklist during construction phase of a bioretention facility.

Module Review

Module 6 – Bioretention



Understand the basics of bioretention facility construction, maintenance and testing:

- ▶ Recognize the appropriate application of equipment for the construction & maintenance of a bioretention practice.
- ▶ Identify the various activities related to routine maintenance of a bioretention facility.
- ▶ Identify signs that immediate maintenance is needed in a bioretention facility.
- ▶ Recognize a GI related performance issue.
- ▶ Describe the activities and the inspection & maintenance schedule (based on months/seasons) for a bioretention facility.
- ▶ Understand the need for testing to verify performance as well as testing requirements and procedures.

Module Review

Module 7 – Permeable/Porous Pavement



The learning objectives for this module are:

- ▶ Provide an overview of permeable/porous pavements and how they work and are used.
- ▶ Understand the basic types, components, and appropriate uses of permeable pavement systems.
- ▶ Describe the components and basic functionality of:
 - ▶ Porous asphalt
 - ▶ Pervious concrete
 - ▶ Permeable paver systems
 - ▶ Plastic grid systems
- ▶ Identify the signs that a permeable pavement system is not working properly.

Module Review

Module 8 – Rainwater Harvesting



The learning objectives for this module are:

- ▶ Define rainwater harvesting.
- ▶ Know the components and basic functions of rain barrels and cisterns.
- ▶ Understand the basic installation sequence of rain barrels and cisterns.
- ▶ Be able to identify the signs that a rain barrel or cistern is/is not working properly.
- ▶ Identify the basic maintenance necessary to keep rain barrels and cisterns working properly.

Module Review

Module 9 – Green Roofs/Blue Roofs



The learning objectives for this module are:

- ▶ Understand the types, components and basic functions of green and blue roofs.
- ▶ Know the basic installation sequence of green and blue roofs.
- ▶ Be able to identify the signs that a green or blue roof is working properly.
- ▶ Understand the basic maintenance necessary to keep a green or blue roof working properly.

Module Review

Module 10 – Dry Wells

The learning objectives for this module are:

- ▶ Provide an overview of dry wells – how they function, flow path through and where they are typically used.
- ▶ Describe the components of dry wells and the function/purpose of each component. Identify components in plan and section view.
- ▶ Explain the construction sequence and the importance of each step.
- ▶ Identify special tools or equipment used to construct or maintain dry wells.
- ▶ Identify visible signs that a dry well is or is not operating properly.
- ▶ Describe typical maintenance activities for dry wells.
- ▶ Identify any safety concerns specific to dry wells.
- ▶ Identify key dry well construction, inspection and maintenance information and explain the importance of documenting it properly.



Module Review

Module 11 – Stormwater Wetlands



The learning objectives for this module are:

- ▶ Understand the components and basic functions of stormwater wetlands.
- ▶ Understand the basic installation sequence for stormwater wetlands.
- ▶ Be able to identify signs that a stormwater wetland is functioning properly or not functioning properly.
- ▶ Know the basic maintenance necessary to keep a stormwater wetland functioning properly.

Module Review

Module 12 – Managing Green Infrastructure for Long-Term Performance



The learning objectives for this module are:

- ▶ Understand the significance of record drawings.
- ▶ Know the importance of operations and maintenance plans and appropriate use of photo documentation for construction inspection and long-term operation and maintenance.
- ▶ Recognize the significance of and best practices for an inspection report.
- ▶ Understand the basics of asset management.